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DETERMINATION OF IMPACT PARAMETERS

AVCO SYSTEMS DIVISION
AVCO CORPORATION

TECHNICAL REPORT AFATL-TR-73-14
JANUARY 1973

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AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

EGLIN AIR FORCE BASE, FLORIDA

Determination Of Impact Parameters

Frank R. Lascher

David Henderson

Sol Feldman

FOREWORD

This program was conducted by Avco Systems Division, Avco Corporation, 201 Lowell Street, Wilmington, Massachusetts 01887, under Contract F08635-72-C-0218 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida, during the period 15 July 1972 to 15 December 1972. Lt William H. McMillian (DLJF) was program manager for the Armament Laboratory.

Avco Program Manager was Mr. Frank R. Lascher, Mr. David Henderson was Technical Program Leader and Mr. Sol Feldman was in charge of the structural response aspects of the program. The Avco report number is AVSD-0169-73-RR.

This technical report has been reviewed and is approved.

FENDRICK J. SMITH, Jr., Colonel USAF
Chief, Fuzes and Munition Control
Systems Division

ABSTRACT

This research program was conducted to establish the deceleration environment experienced in the nose and tail fuze wells of the MK82 for bomb impacts into sand targets. The study was conducted for warhead impact velocities of 600, 900, and 1100 ft/sec and impact angles, from the vertical, from 20 to 70 degrees. The contractor's Two-Dimensional Impact and Penetration Computer Program was utilized to establish the time history of the loads applied to the MK82 during the impact and penetration event. This loading environment was then applied to a mathematical structural model of the MK82 to establish the deceleration environments experienced by both fuzes during the penetration event. The results of this analysis indicated that the flexibility characteristics of the warhead have a large influence upon the fuze well deceleration environments and generated deceleration magnification factors as high as 1.8.

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NOMENCLATURE

Symbol	Definition
$X'Y'Z'$	Body fixed coordinate system, i.e., Z' aft along the axis X' Positive, right, perpendicular to the axis of the projectile Y' forms the orthogonal triaxial
dF	elemental force, lbs
η	medium resistance coefficient, psi
ϕ	azimuth position of elemental area dA, (rotation about axis), rad
θ	local 1/2 cone angle, degrees
dA_p	elemental projected area = f (angle of atta κ and θ), in.^{2}
L	local angle of attack, rad
dA	elemental surface area, in.^{2}
F_f	friction force due to medium resistance
f_c	coefficient of friction
F_N	normal force due to medium resistance
ρ	medium density, slugs/in.^{3}
ζ	the angle between the local velocity vector and the elemental surface area, rad
V_N	local normal velocity vector, in./sec
$\dot{Z}_L$ and $\dot{X}_L$	local velocity components, in./sec
$\dot{Z}_I$ and $\dot{X}_I$	velocity components in the inertial coordinate system (vehicle center of gravity), in./sec
$S(i)$	axial distance of elemental surface from vehicle C_g, in.
$\dot{\gamma}$	vehicle pitch rate, rad/sec
$r(i)$	radial station of elemental surface area, in.
dM_c	elemental moment about C_g of projectile

SECTION I

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

To design a fuzing system for operation in a bomb which will impact and penetrate into a soil, sand, or concrete target, one should be knowledgeable of the high deceleration environment experienced during the impact event in which the fuze will be required to survive and/or function. This is necessary to ensure that the fuze designer has the information necessary to design the fuze structural components and functioning characteristics to perform in and/or survive the deceleration environments associated with the full range of bomb and target impact parameters. In addition, any functional or environmental tests conducted on an existing or developmental system lack meaning unless one can be assured that the environments which are simulated in the tests duplicate the in-use environments in which the unit must function. For these reasons it is desirable that the fuze designer have available to him a series of tables, charts, or graphs which parametrically specify the fuze impact environment as a function of bomb configuration, bomb impact geometry, and target characteristics.

To satisfy this long-term Air Force objective, a series of analytical and experimental programs have been initiated by the Air Force Armament Laboratory (AFATL) to expand the data base in this area and to provide preliminary information for specific impact conditions. This program was conducted to investigate the deceleration environments experienced by the nose and tail fuzes of the MK82 for bomb impacts into sand targets. This was accomplished utilizing the technology developed under Contracts AF 29(601)-7177 and F29601-68-C-0066, sponsored by the Air Force Weapons Laboratory, and serves as a continuation of the effort initiated under Contract F08635-69-C-0193, sponsored by AFATL. Basically, complete histories of the MK82 nose and tail fuze accelerations were determined analytically for a variety of warhead impact conditions into sandy terrain.

1.2 SUMMARY

To obtain the MK82 fuze deceleration environments for warhead impacts into sand targets, a four-part study was conducted. The initial activity consisted of determining the impact loads acting on the MK82 for the impact conditions specified in Table I. This was accomplished utilizing the contractor's two-dimensional Impact and Penetration Computer Code which specified the time history of the forces acting on the MK82 and the resultant warhead deceleration for impacts into the sand target.

TABLE I. TABLE OF TRAJECTORIES OF THE MK82 MOD 1 500-LB. BOMB INTO A SAND TARGET

Case Number	γ_I, deg (From Vert.)	V_I	
		Ft/sec	In./sec
1	20	1,100	13,200
2	25		
3	30		
4	35		
5	40		
6	45		
7	50		
8	55		
9	60		
10	65		
11	70		
12	20	900	10,800
13	25		
14	30		
15	35		
16	40		
17	45		
18	50		
19	55		
20	60		
21	65		
22	70		
23	20	600	1,200
24	25		
25	30		
26	35		
27	40		
28	45		
29	50		
30	55		
31	60		
32	65		
33	70		

The second activity consisted of the generation of a dynamic mathematical model of the MK82. The structural layout of the MK82 which was used for this study is shown in Figure 1.

The next phase consisted of determining the structural response of the MK82 nose and tail fuzes by applying the loading environment established in Task 1 to the structural model generated in Task 2 and establishing the resultant deceleration environments. A summary of the results, i.e., the peak acceleration environments, is shown in Figures 2 through 5. The axial and transverse accelerations for the forward fuze are shown in Figures 2 and 3, respectively, while the axial and transverse accelerations for the aft fuze are presented in Figures 4 and 5, respectively. These peak levels occur during the first few milliseconds of the penetration event. These early peaks are due to the flexibility of the MK82 bomb and, in most cases, are significantly greater than the rigid body response which reaches a maximum later in the trajectory.

The magnifications of the peak deceleration loads caused by the flexibility of the MK82 were as high as a factor of 1.8. This clearly demonstrates that the flexibility characteristics of the warhead must be considered to establish peak fuze impact decelerations. This magnification factor will be substantially higher for bomb impacts into media which have a higher acoustic impedance than sand. Examples of these media include clay, frozen earth, and concrete.

The results of this program, therefore, provide the fuze designer with detailed information concerning MK82 impact environments. This should not be considered an end in itself, but a first step in the better understanding of fuze loading environments. For this reason, this effort should be expanded to include additional impact media and warheads to provide a more complete data base for the fuze designer.

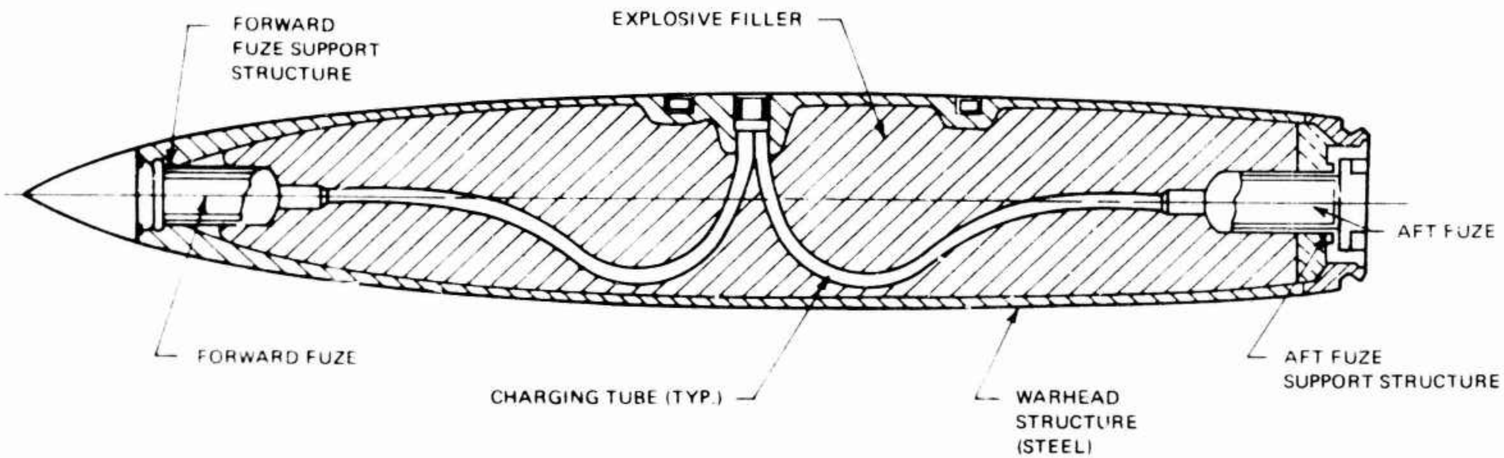

Figure 1 MK82 BASIC CONFIGURATION STRUCTURAL DRAWING

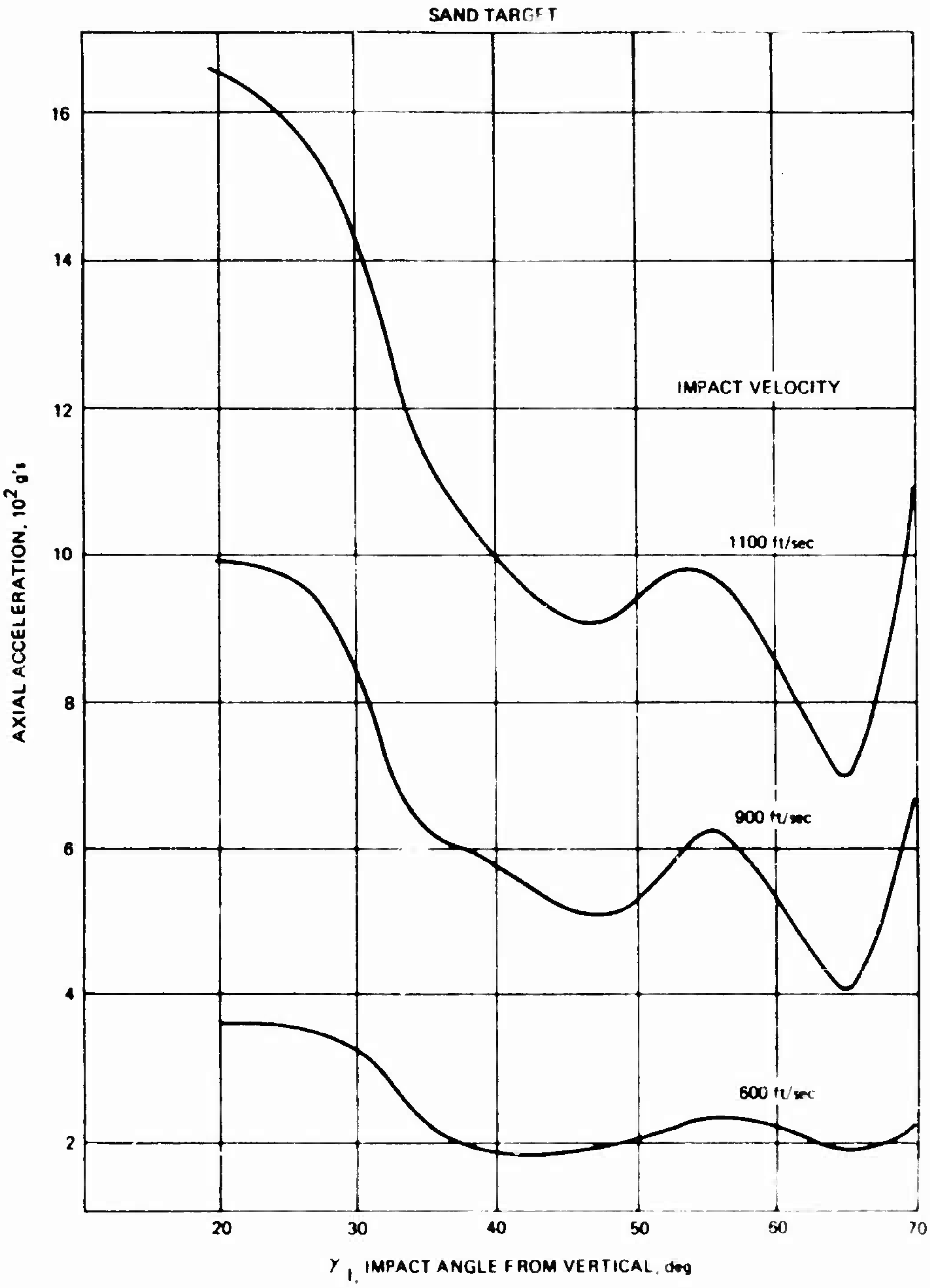

Figure 2 MK82 FORWARD FUZE AXIAL ACCELERATION

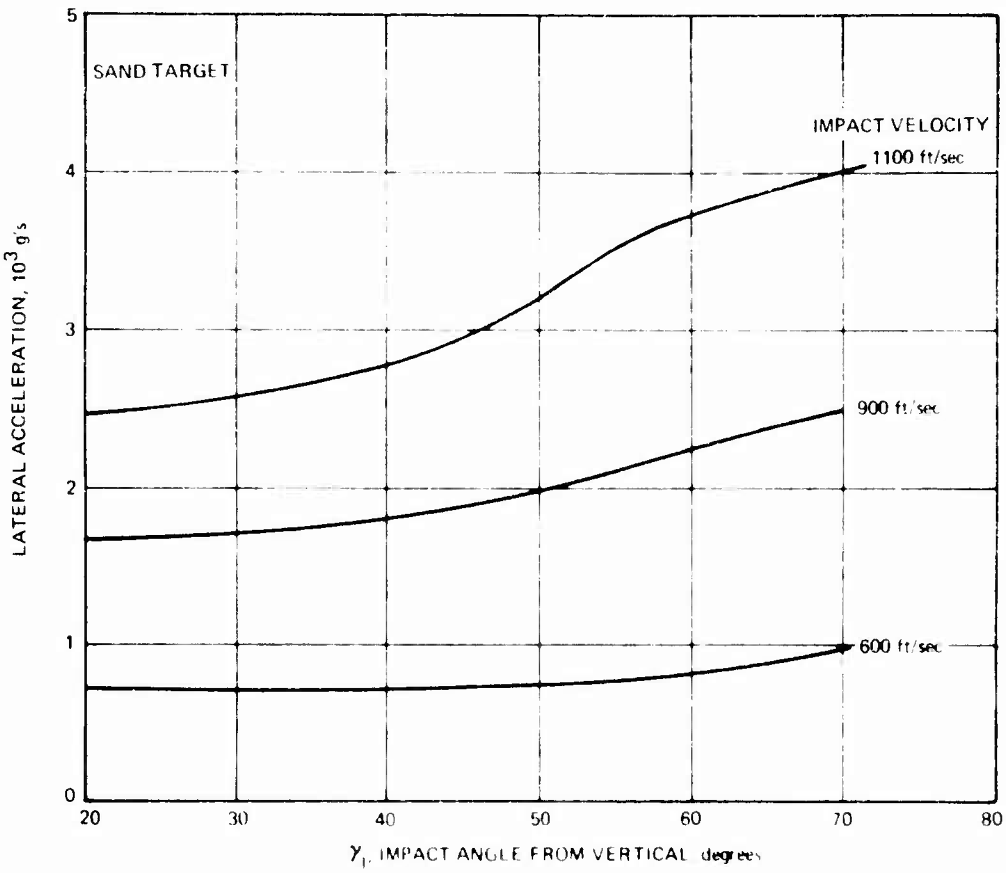

Figure 3 MK82 FORWARD FUZE LATERAL ACCELERATION

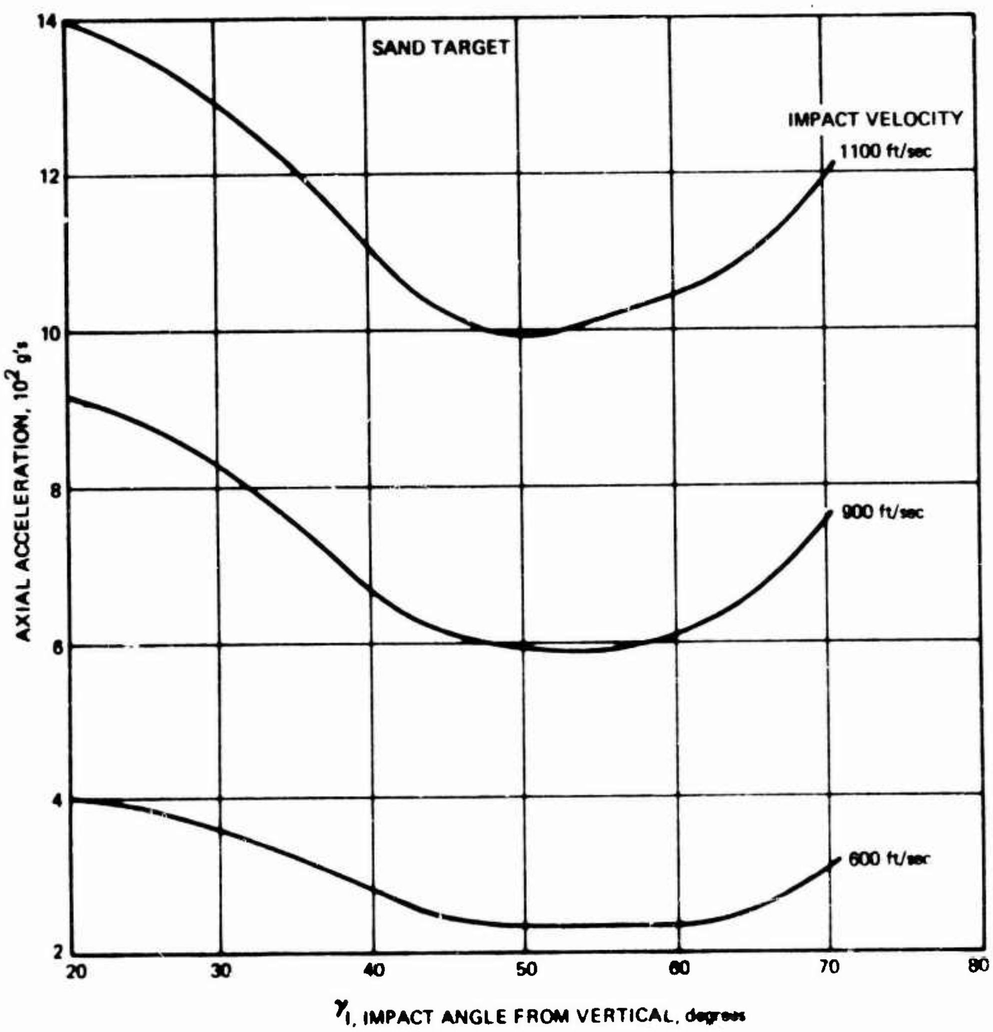

Figure 4 MK82 AFT FUZE AXIAL ACCELERATION

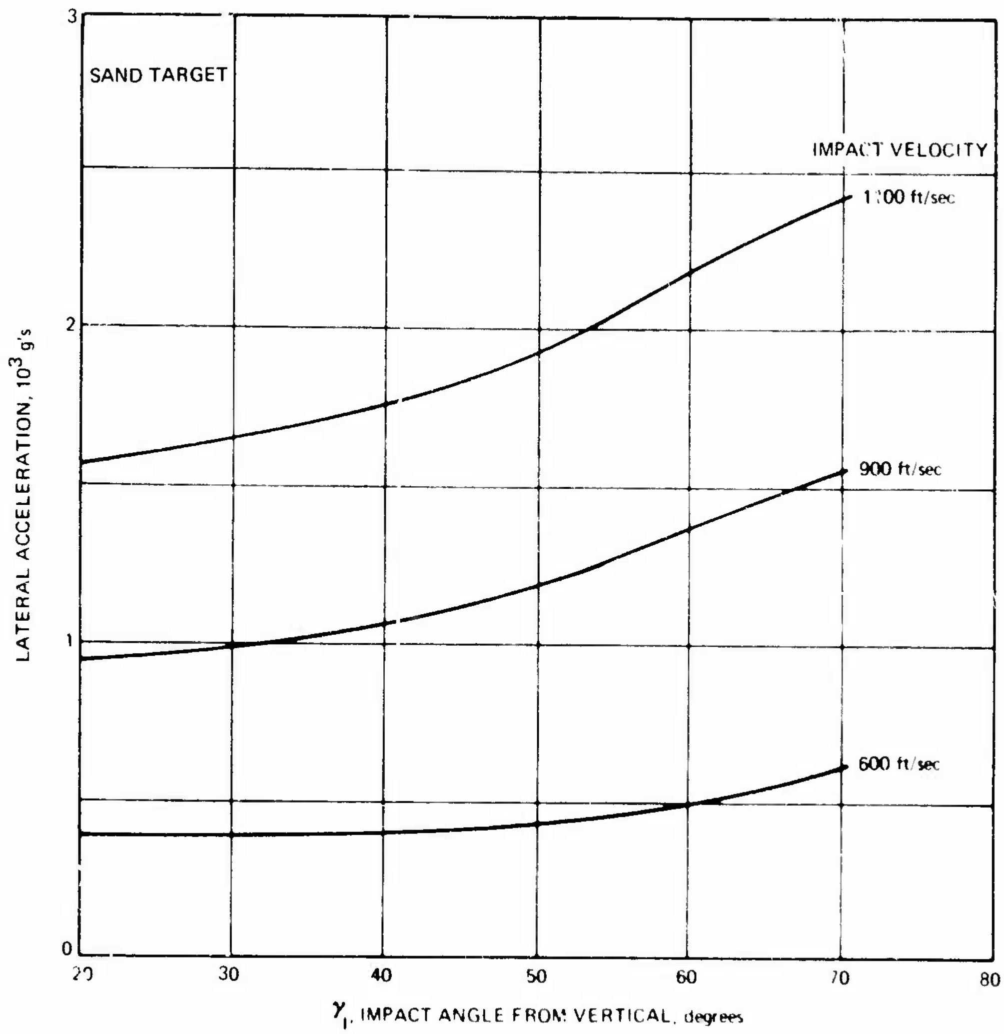

Figure 5 MK82 AFT FUZE LATERAL ACCELERATION

SECTION II

TECHNICAL DISCUSSION

2.1 INTRODUCTION

The objectives of this program were to determine the MK82 bomb fuze acceleration environments due to impacts into sand. This problem is schematically represented in Figure 6. The locations of the forward and aft mounted fuzes are designated. Due to the impact, penetration, and/or ricochet event, transverse and axial accelerations of the fuze systems are experienced as shown. The total accelerations experienced by any station on the warhead is due to the combined elastic plus rigid body accelerations. It was the purpose of this program to determine this total acceleration environment. The environment varies as a function of impact velocity and warhead orientation. The matrix of impact conditions investigated during this study is shown in Table I.

The approach taken to meet the objectives of the program involved the conduct of several tasks. These included

1. Loading Environment Analysis - This study also established the MK82 rigid body response.

2. Generating a dynamic mathematical model of the MK82 configuration.

3. Determining the structural response of the MK82 bomb due to the loading environment established in (1), above.

4. Combining the resulting environments to determine the total acceleration histories of the forward and aft fuze systems.

Each of these study tasks is described in the paragraphs that follow.

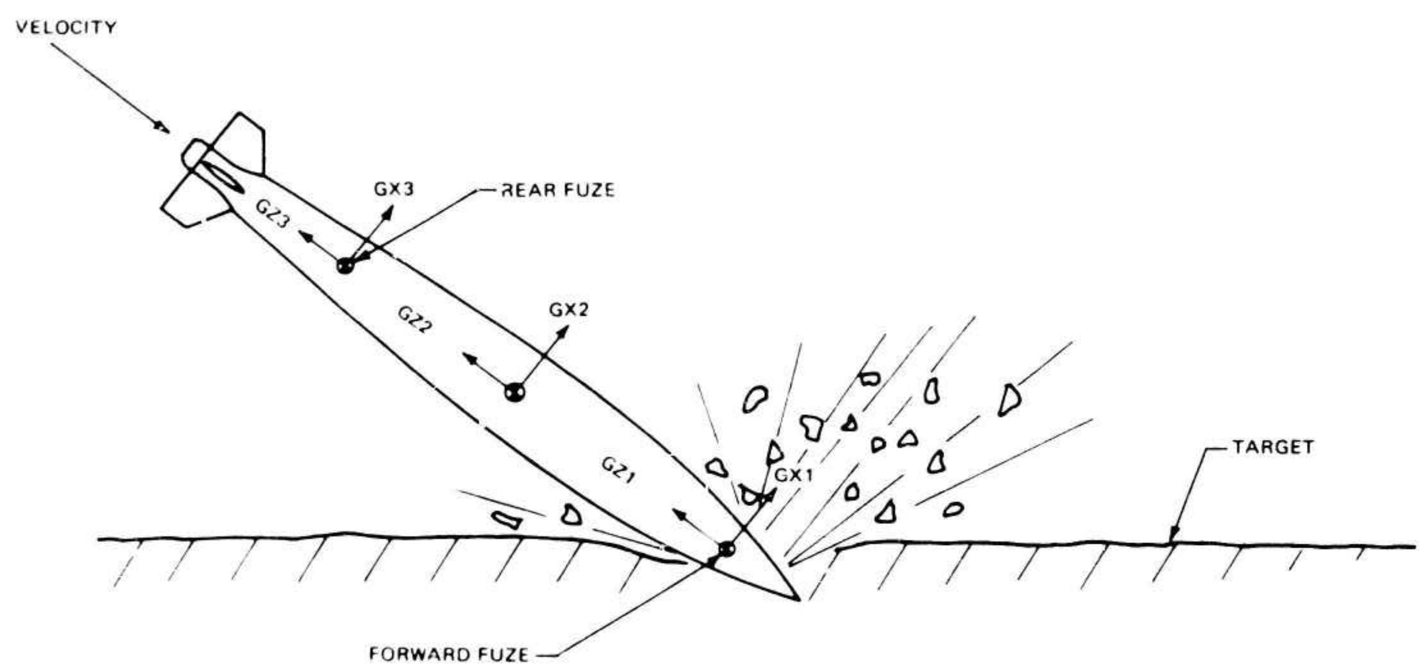

Figure 6 MK82 SAND IMPACT EVENT AND NOMENCLATURE

2.2 LOADING ENVIRONMENTS ANALYSIS

The purpose of the loading environment analysis was to determine the loads acting on the MK82 projectile due to impacts into sand. In view of the fact that the loads are dependent upon the state of the projectile (i.e., its position and velocity relative to the impacted medium), this data, which represents the projectile rigid body response, is determined concurrently with the loading environment.

The capability to perform this type of theoretical analysis with confidence that the predicted loads accurately describe the actual impact environment is due to the contractor's general background in the technological field and, specifically, his participation in the 155mm Fuze Environments Program. The objective of this program was to establish the analytical capability to predict impact environments into sand. This was accomplished, and was verified by test. A summary of that program is included in Appendix I.

The results of that program made available the resistance to penetration force law for sand which is described below.

<u>Dynamic Penetration Force Law for Sand</u>

The basic form of the force law is:

Resistance force = compressibility effects (i.e., shock) +→

Medium resistance pressure +→ medium resistance friction

+→ equivalent fluid dynamic normal pressure

+→ equivalent shear drag +→ separation

+→ cratering +→ target surface effects

It is believed that all the pertinent physical phenomena to which a projectile can be subjected during impact into sand are represented above.

The mathematical equivalent expression for the above force law is expressed:

$$dF = dA\,[\rho c v e^{-\alpha t}\,u(t-\tau) + \eta + C_N k V^2 + C_\tau k V^2] + \text{Target surface effects}$$

This force law is described in detail in the following paragraphs. Also given are specific values of the governing coefficients.

Medium Resistance Phenomena

Pressure Force

This term is the resistance to penetration associated with the medium characteristics themselves. This term is that resistance necessary to part the medium and allow passage of the projectile, neglecting those forces generated from the inertia of the impacted particles. If the medium were steel or concrete, this resistance would be very high and would be proportional to the failure strength of the material itself.

In the case for sand, this pressure was considered to be relatively small and was found to be on the order of 10 psi near the surface for both sand and soil. Its direction of application is normal to the surface of the projectile, and its magnitude is modified in proportion to the projected cross-sectional area of the elemental area under consideration.

In analytical form, the elemental forces due to the medium resistance pressure are:

$$(dF_x')_m = -\eta \sin\phi \cos\theta \, dA_p$$

$$(dF_x')_m = -\eta \sin\phi \cos\theta \sin(\theta + \alpha_L \sin\phi) \, dA$$

and

$$(dF_z')_m = -\eta \sin\theta \sin(\theta + \alpha_L \sin\phi) \, dA$$

All of the forces shown here and subsequently are resolved from the elemental surface area to the body fixed coordinate system which includes the axial, designated Z', and the transverse, designated X'.

Friction Force

The medium resistance friction force is defined in the usual way, i.e., its magnitude is equal to the normal force (derived above) times a friction coefficient (f_c), and its direction of application lies in the plane of the elemental surface area.

In analytical form,

$$(F_f) = f_c (F_N)$$

$$(F_N) = \eta \, dA_p = \eta \sin(\theta + \alpha_L \sin\phi) \, dA$$

$$(dF_{fx}') = -f_c \eta \sin\phi \sin\theta \sin(\theta + \alpha_L \sin\phi) \, dA$$

$$(dF_{fz}') = f_c \eta \cos\theta \sin(\theta + \alpha_L \sin\phi) \, dA$$

In this instance, f was found to be 0.25. The level of the resulting forces due to this term are, however, relatively insignificant.

Equivalent Fluid Dynamic Resistance Forces

The equivalent fluid dynamic resistance forces are generated from the inertial resistance to motion of the sand particles being impacted by the penetrator. The model used here to represent flow characteristics is the extended Newtonian impact theory. In this theory accommodation coefficients are introduced to account for the nature of the detailed interaction between the sand particle and the body surface.

Of interest here are two of the coefficients C_N, the normal accommodation coefficient, and C_τ, the tangential accommodation coefficient. These coefficients are a measure of the proportion of incident normal momentum and tangential momentum that is transferred to the sand particles as a result of collision with the surface of the projectile and therefore are a measure of the amount of momentum imparted to the projectile. This theory postulates that the normal pressure P and shear stress τ at the surface are given by:

$$P = 1/2\ C_N\ \rho\ V^2 \sin^2 \xi$$

$$\tau = 1/2\ C_\tau\ \rho\ V^2 \sin\xi \cos\xi$$

The range of values of these coefficients can be established by considering the fundamental laws of physics. For purely elastic impact of a sand particle where the rebound velocity is equal to the impact velocity, C_N would take on the value of 4.0 while $C_\tau = 0$. This type of situation, sometimes referred to as completely specular reflection, has no energy loss and consequently establishes the maximum value of C_N and the minimum value of C_τ. The other limiting case occurs when $C_N = 2$ and $C_\tau = 2$. This represents the situation when purely inelastic momentum transfer has taken place and is referred to as "completely diffuse reflection". These boundary conditions on the coefficients modifying the shear and pressure fluid dynamic terms in the force law were recognized and adhered to. The final values of C_N and C_τ were found to be within these limits but were also found to be a function of velocity. The curve shown in Figure 7 represents the experimentally determined values for sand of the velocity dependence of C_N and C_τ.

The analytical expression used in the two-dimensional simulator for these transverse and axial elemental forces are:

$$(dF_x')_{flow} = -\ (P \sin\phi \cos\theta + \tau \cos\xi \cos\phi)\, dA$$

$$(dF_z')_{flow} = (P \sin\theta - \tau \sin\xi \cos\theta)\, dA$$

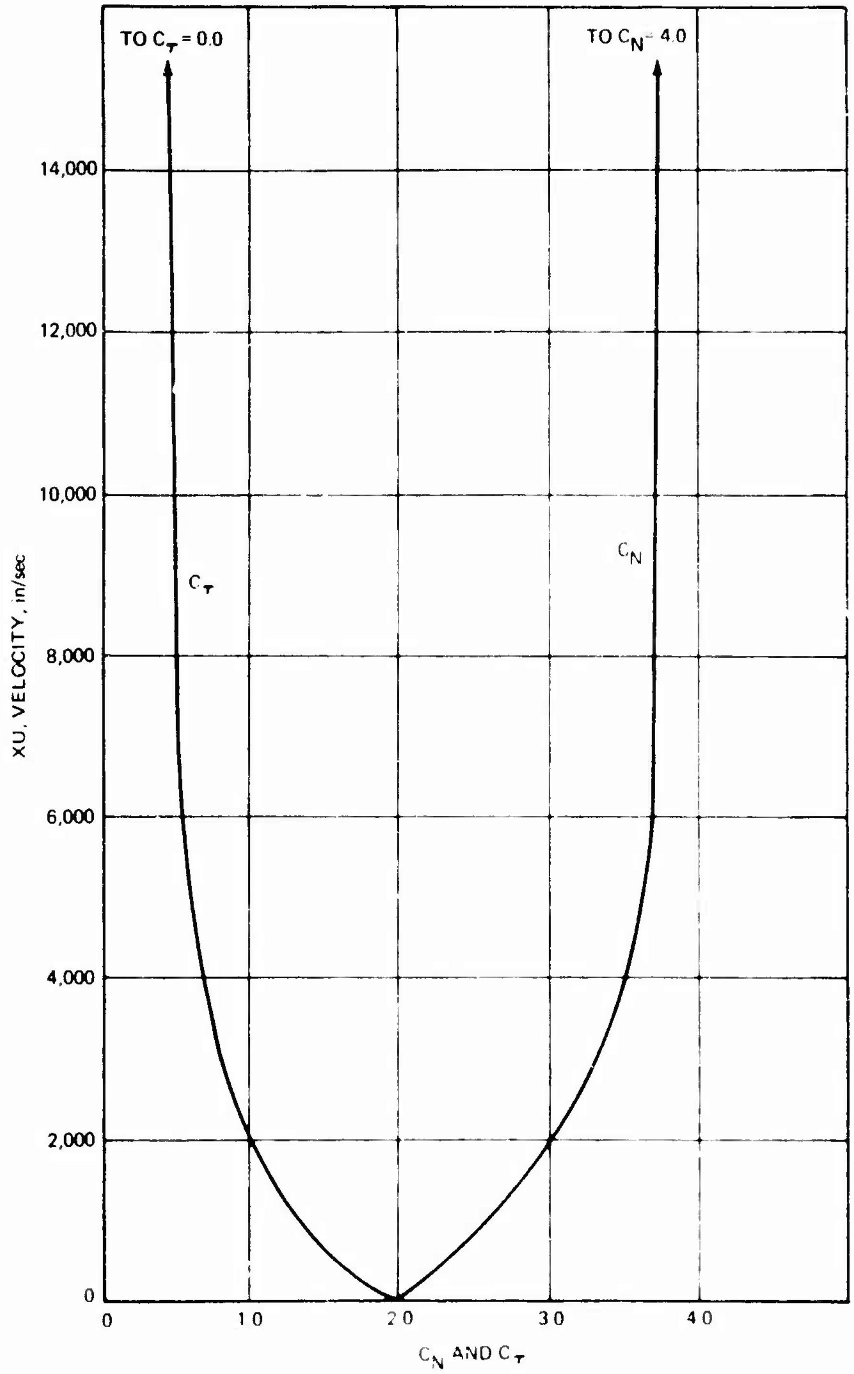

Figure 7 VELOCITY DEPENDENCE OF C_N AND C_T – SAND

Flow Separation Phenomena

Flow separation is a natural phenomenon which simply allows portions of the surface of the projectile to be free of resistance to penetration forces. This occurs whenever the local flow condition is outward from the surface. The parameter which governs whether forces exist is the sign of the local normal velocity vector, V_N.

If the sign is positive, then the flow is inward against the surface, and if negative, the flow is outward from the surface and no forces exist. This phenomenon is handled, therefore, by limiting the integration over the surface of the projectile to those areas where V_N is positive.

For any location on the surface of the projectile,

$$V_N = (-S\,\theta C\,\gamma + C\,\theta S\,\phi S\,\gamma)\,\dot{Z}_L + (S\,\theta S\,\gamma + C\,\theta S\,\phi C\,\gamma)\,\dot{X}_L$$

where

$$\dot{Z}_L = \dot{Z}_I + S(i)\,\dot{\gamma}\,\sin\gamma$$

$$\dot{X}_L = \dot{X}_I + \dot{\gamma}\,S(i)\cos\gamma$$

Values of ϕ are determined when V_N goes to zero. These become integration limits over which resistance to penetration forces can exist.

Target Surface Effects

The phenomenon of target surface effects is shown schematically in Figures 8 and 9. The phenomenon was utilized in the simulations to allow for the lowering of resistance to penetration near the surface of the sand target.

The influence of target surface effects is a function of distance between the projectile and the target surface. This relationship for MK82 impacts into sand is shown in Figure 10. This variation occurs at the surface and down to a depth of 100 inches and allows the upper surface of the projectile to be unloaded with a linear variation of the load to a maximum at the base. VCHIPF is the percentage of unloading and varies as a function of depth as shown.

Resulting Force Law

The analytical expressions for the forces and moments, i.e., the force law, which made up the combination of the above effects is:

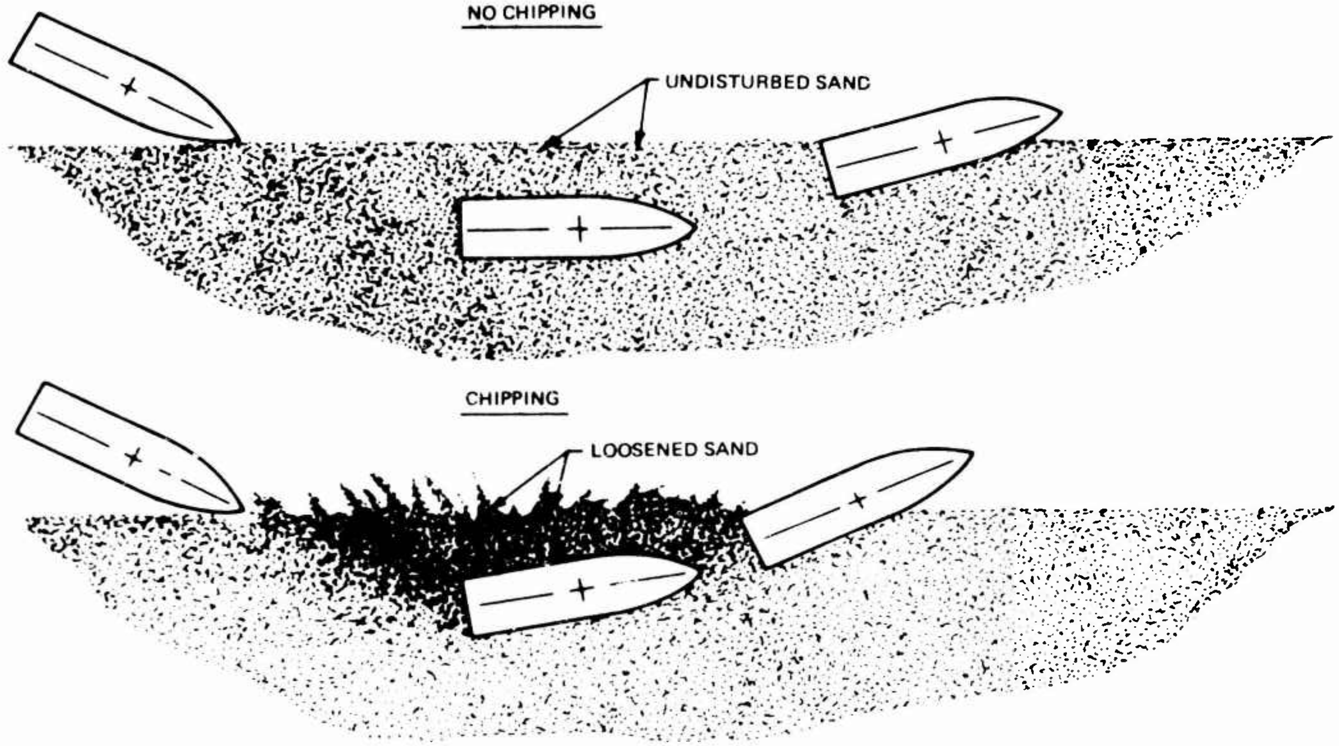

Figure 8 SURFACE OR EDGE EFFECTS

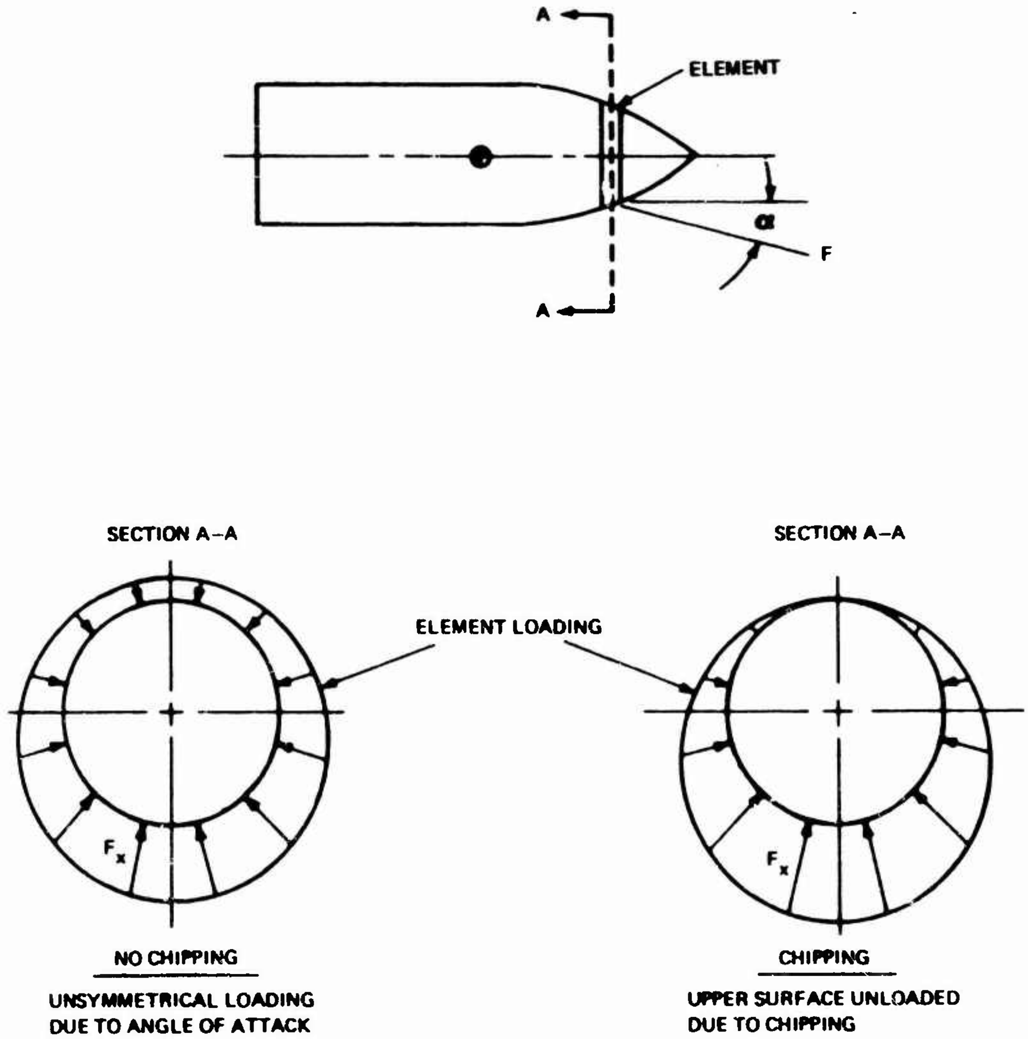

Figure 9 LOADING DUE TO SURFACE EFFECTS

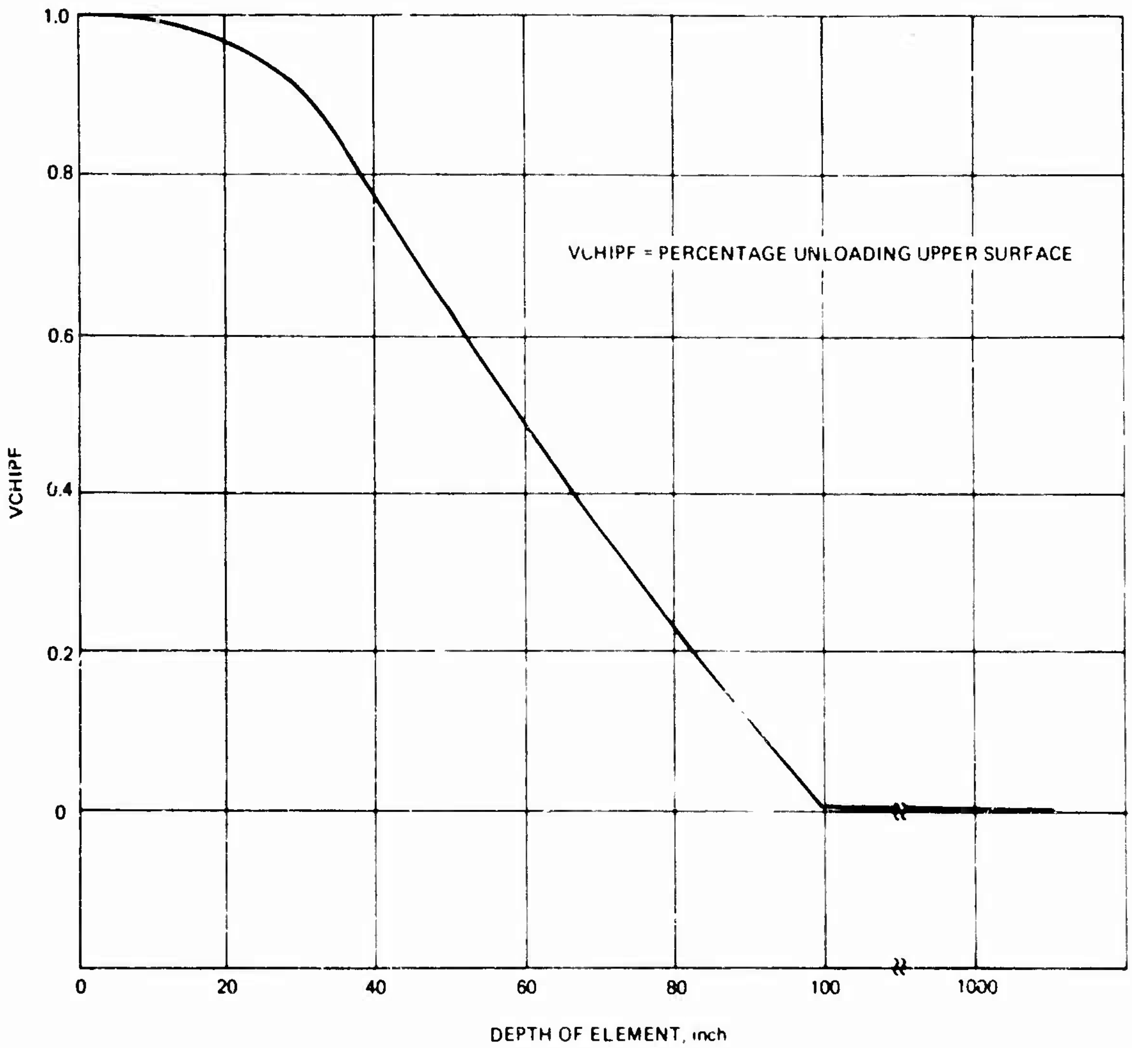

Figure 10 UNLOADING DUE TO SURFACE EFFECTS

For the transverse loads,

$$dF_{x'} = (dF_{x'})_m + (dF_{x'})_f + (dF_{x'})_{flow}$$

$$dF_{x'} = -\eta \sin\phi \cos\theta \sin(\theta + \alpha_L \sin\phi)\,dA$$

$$- f_c \sin\phi \sin\theta \sin(\theta + \alpha_L \sin\phi)\,dA$$

$$- (P \sin\phi \cos\theta + \tau \cos\xi \cos\phi)\,dA$$

and for the axial loads,

$$dF_{z'} = (dF_{z'})_m + (dF_{z'})_f + (dF_{z'})_{flow}$$

$$dF_{z'} = \eta \sin\theta \sin(\theta + \alpha_L \sin\phi)\,dA + f_c \cos\theta \sin(\theta + \alpha_L \sin\phi)\,dA$$

$$+ (P \sin\theta - \tau \sin\xi \cos\theta)\,dA$$

The moment is determined by establishing the point of application of the above forces. All these forces act at a station measured from the center of gravity of the projectile and at a radius $r(i) \sin\phi$ from the longitudinal axis of the projectile.

$$dM_c = (dF_{x'})\,S(i) + (dF_{z'})\,r(i) \sin\phi$$

It is apparent that, in view of the fact that the above force law is presented in differential form, a mechanism or tool is needed to integrate these elemental forces over the surface of the projectile and at the same time simulate impact, penetration, and/or ricochet-type phenomena. Such impact phenomena are depicted in Figure 11. From the figure it is also apparent that the rigid body equations of motion must also be solved continuously during the impact event.

The mechanism by which the contractor accomplishes the above tasks is through the use of impact and penetration simulators. The simulator used for the present program is the contractor's 2-Dimensional Impact and Penetration Simulator, i.e., 2-D Code.

Two-dimensional representation of the impact events was considered adequate for the kinds of impact conditions investigated. Basically, the 2-D Code performs all the functions needed to analytically simulate impact-type events. The code:

- Contains the general force law.
- Integrates the forces over the surface of the projectile.
- Solves the rigid body equations of motion.

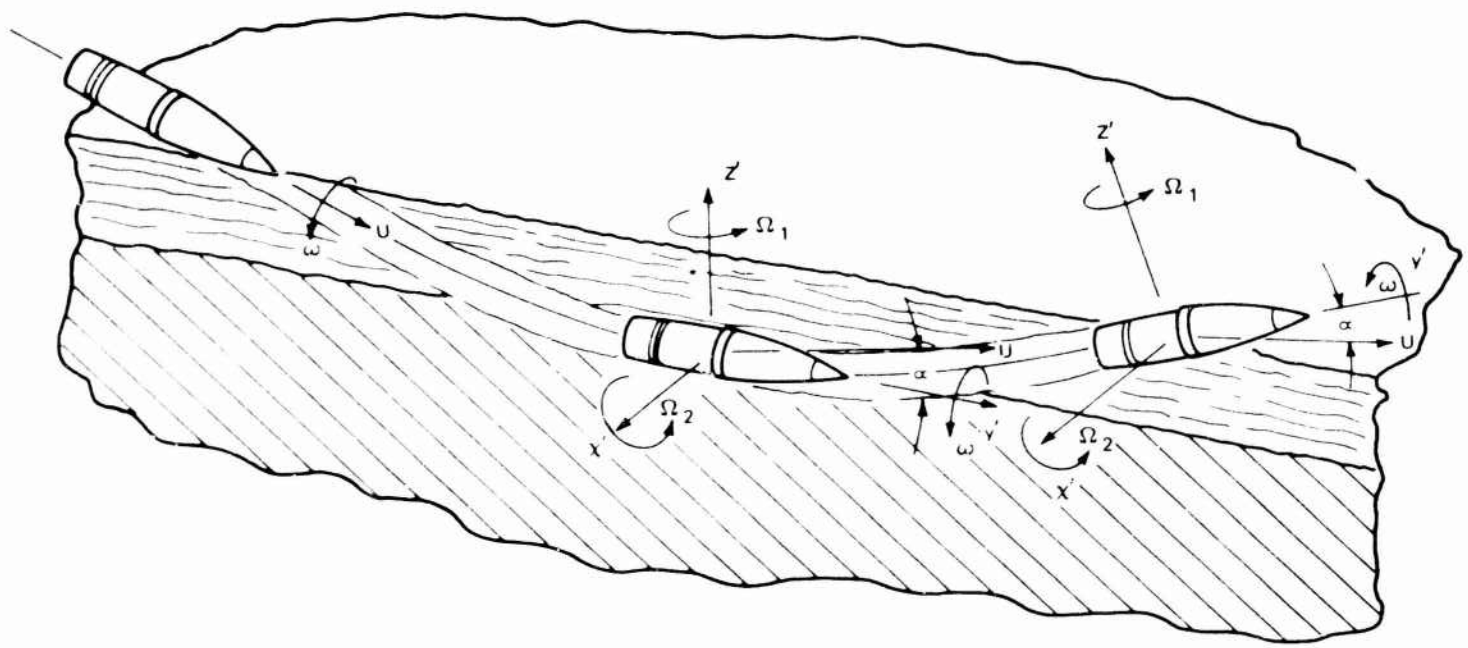

Figure 11 TYPICAL IMPACT AND PENETRATION PHENOMENA

A more detailed description of this code is given in Appendix II; however, an understanding of the 2-D Code's capabilities will be gained through the discussion of its use during this program.

The basic inputs to the 2-D Code included the impact conditions shown in Table I, the force law coefficients described above, the mechanical properties of dry sand, and the MK82 external configuration and its mechanical characteristics. These later data are summarized in Figure 12. It should be noted that the tail structure is not included in the configurational drawing shown in Figure 12. A basic assumption was made in this regard, i.e., that the tail surface failed early during the penetration event and as a result transmitted little inertial reaction to the rest of the body structure. With this data, a rigid body impact parametric study was conducted. The pertinent results generated by this study included:

1. The loading environments
2. The MK82 rigid body response.

All of this data has been delivered to the Air Force under separate cover. An example of the data format is included here in Figures 13 through 17.

The specific example chosen considers the MK82 impacting sand at a velocity of 1100 fps and at an obliquity angle of 70 degrees measured from the vertical.

The standard output format of the 2-D Code consists of a graphical representation of all pertinent trajectory parameters. Five separate graphs are produced. Figure 13 presents the loading environment, where FZP is the axial resistance to penetration resultant force time history, lb, FXP is the transverse force, lb and MCG is the applied moment acting about the center of gravity of the projectile, in lb. The rotational acceleration is obtained by dividing MCG by the mass moment of inertia of the MK82, i.e., (MCG/424, rad/sec^2). Figure 14 represents the basic trajectory data of the impact event where X and Z represent linear displacements as a function of time, inches. VEL is the instantaneous velocity, in/sec, GAM is the orientation in degrees as measured from the vertical, and ALPHA is angle of attack, degrees. Figures 15 and 16 show the axial and transverse accelerations, respectively, in g's. GZ1, GZ2, and GZ3, for example, represent the axial g's at the forward fuze well, the center of gravity, and the aft fuze well, respectively. Figure 17 shows a schematic representation of the trajectory.

In addition to the above data, the distributed loading environments history was determined for each of these impact conditions. This data is so voluminous as to be impractical to produce on hard copy. This data was, however, needed to perform subsequent structural response analysis. In view of this, a modification was made to the basic 2-D Code to output the transient distributed loading environment on magnetic tape. The usage of this data will be discussed in subsequent paragraphs.

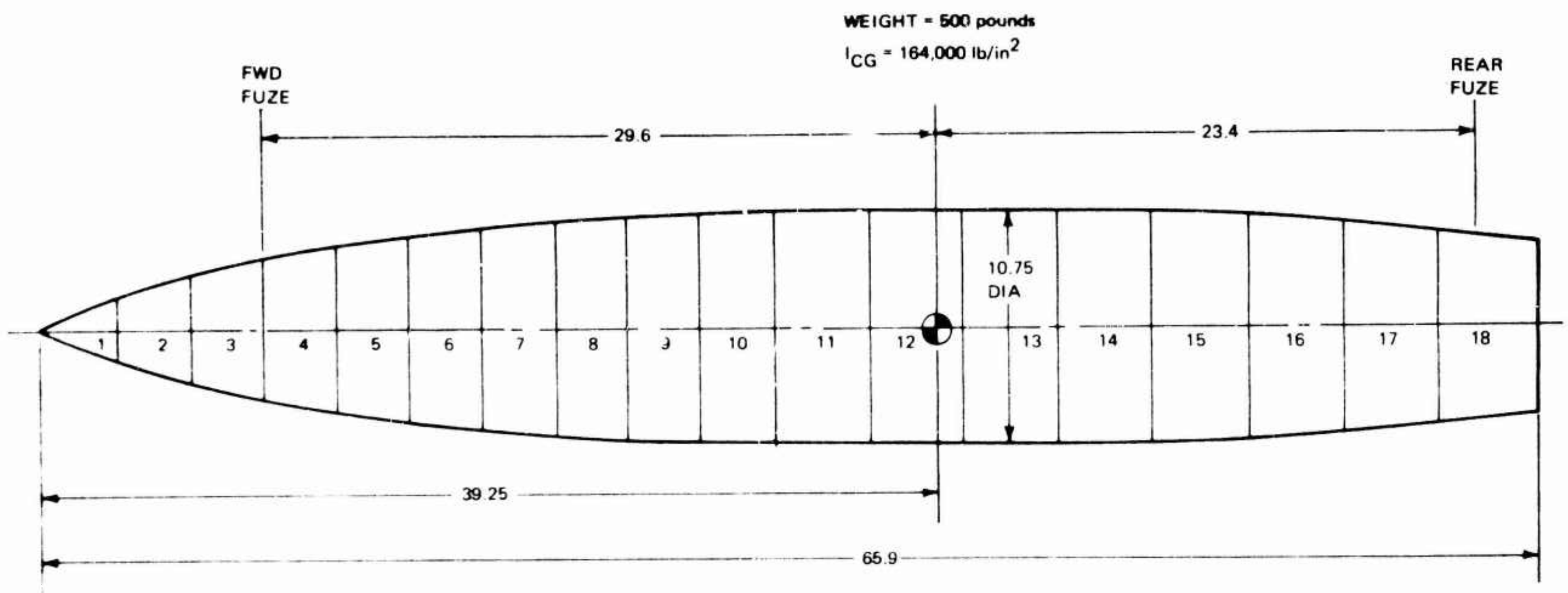

Figure 12 MK82 BOMB

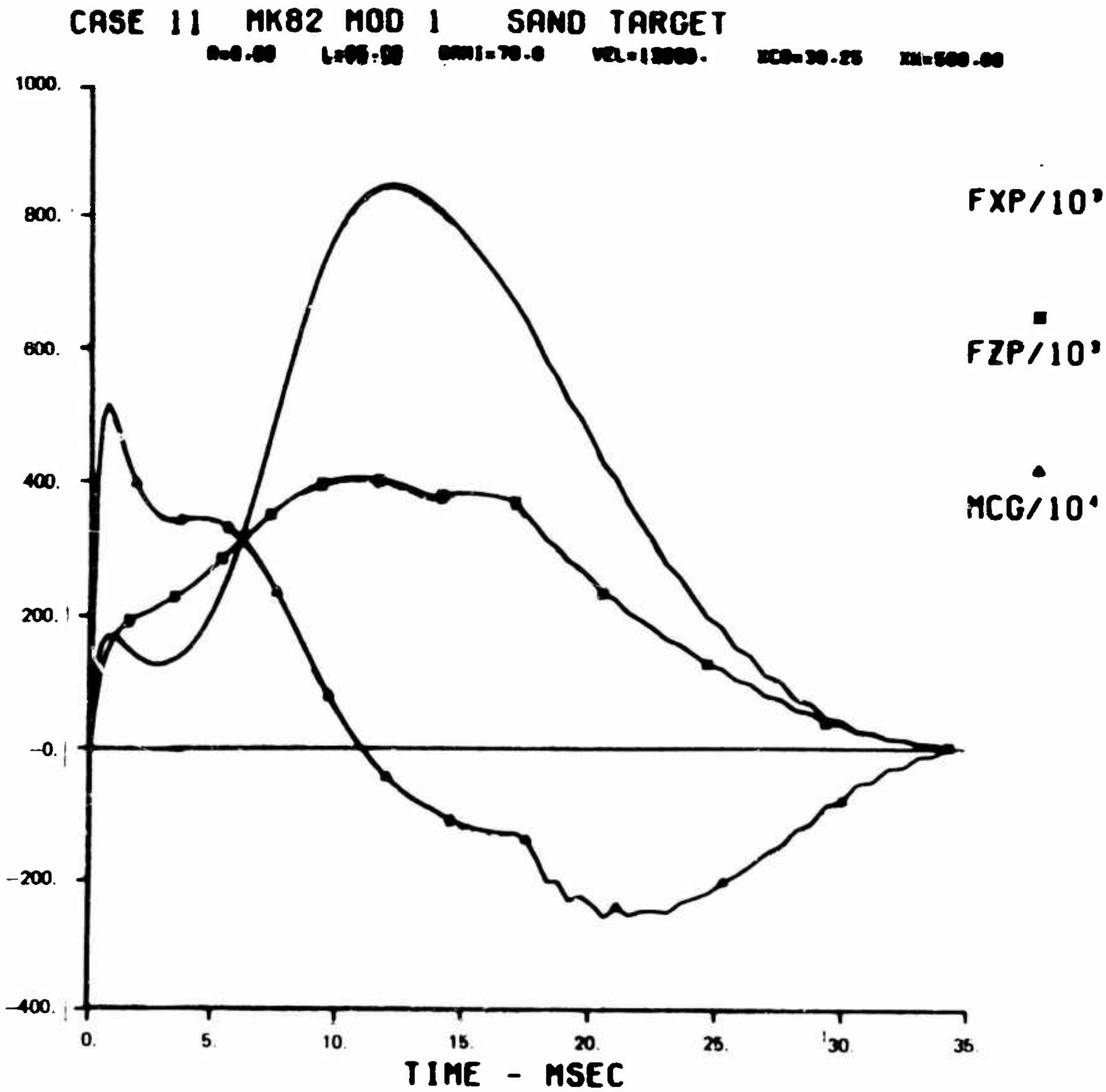

Figure 13 RESULTANT LOADING ENVIRONMENT

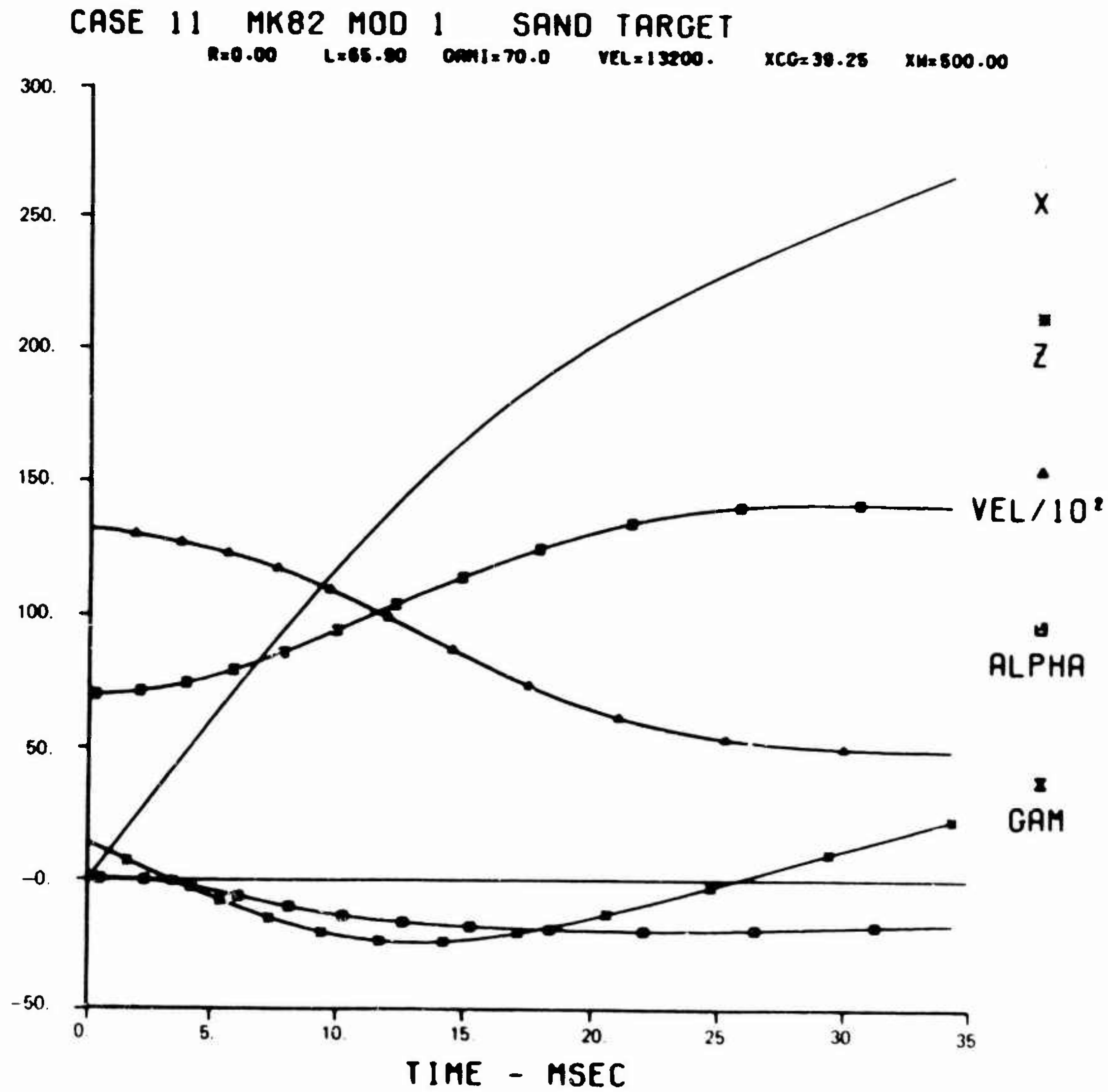

Figure 14 TRAJECTORY DATA

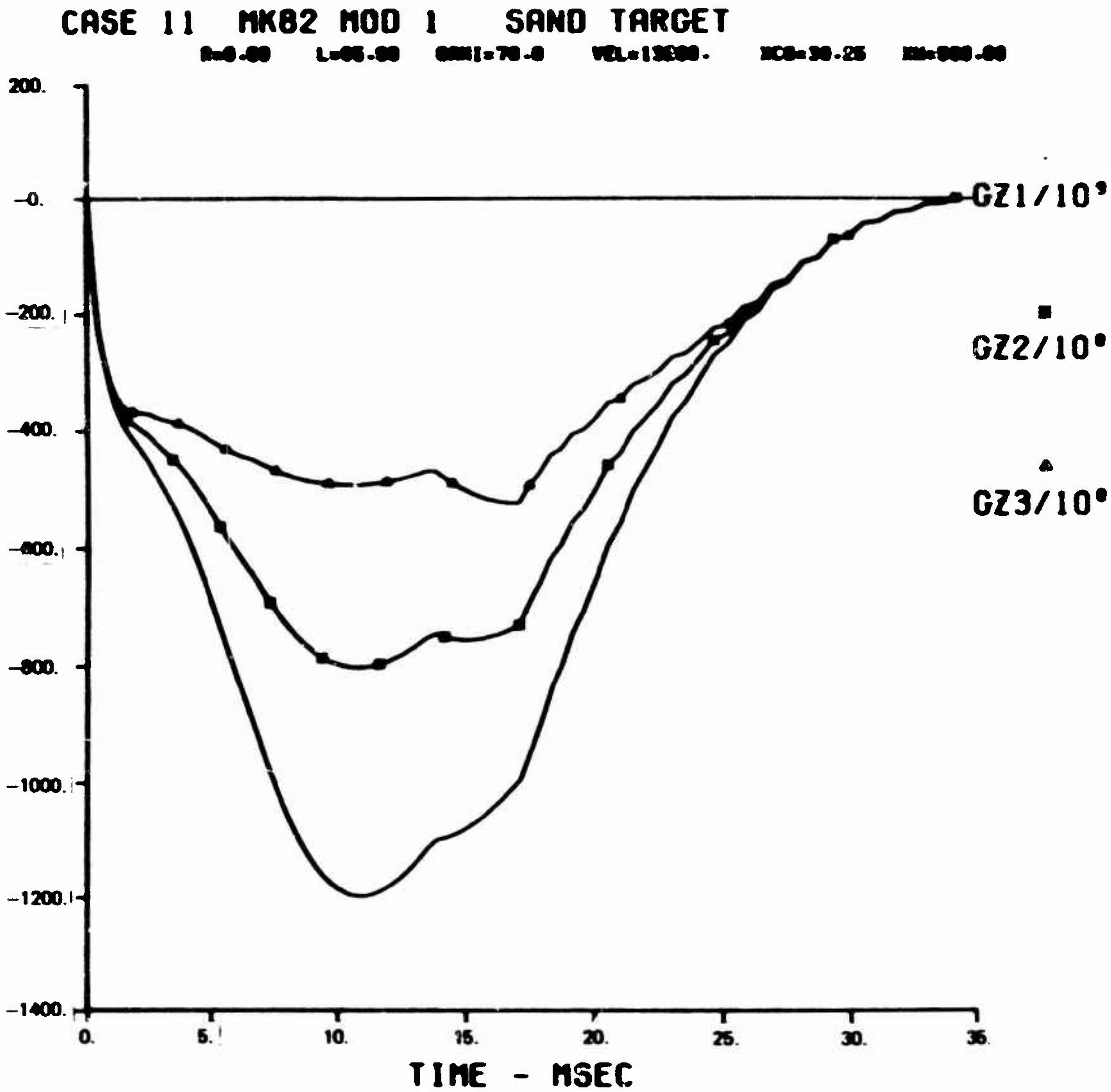

Figure 15 ACCELERATION ENVIRONMENT – AXIAL

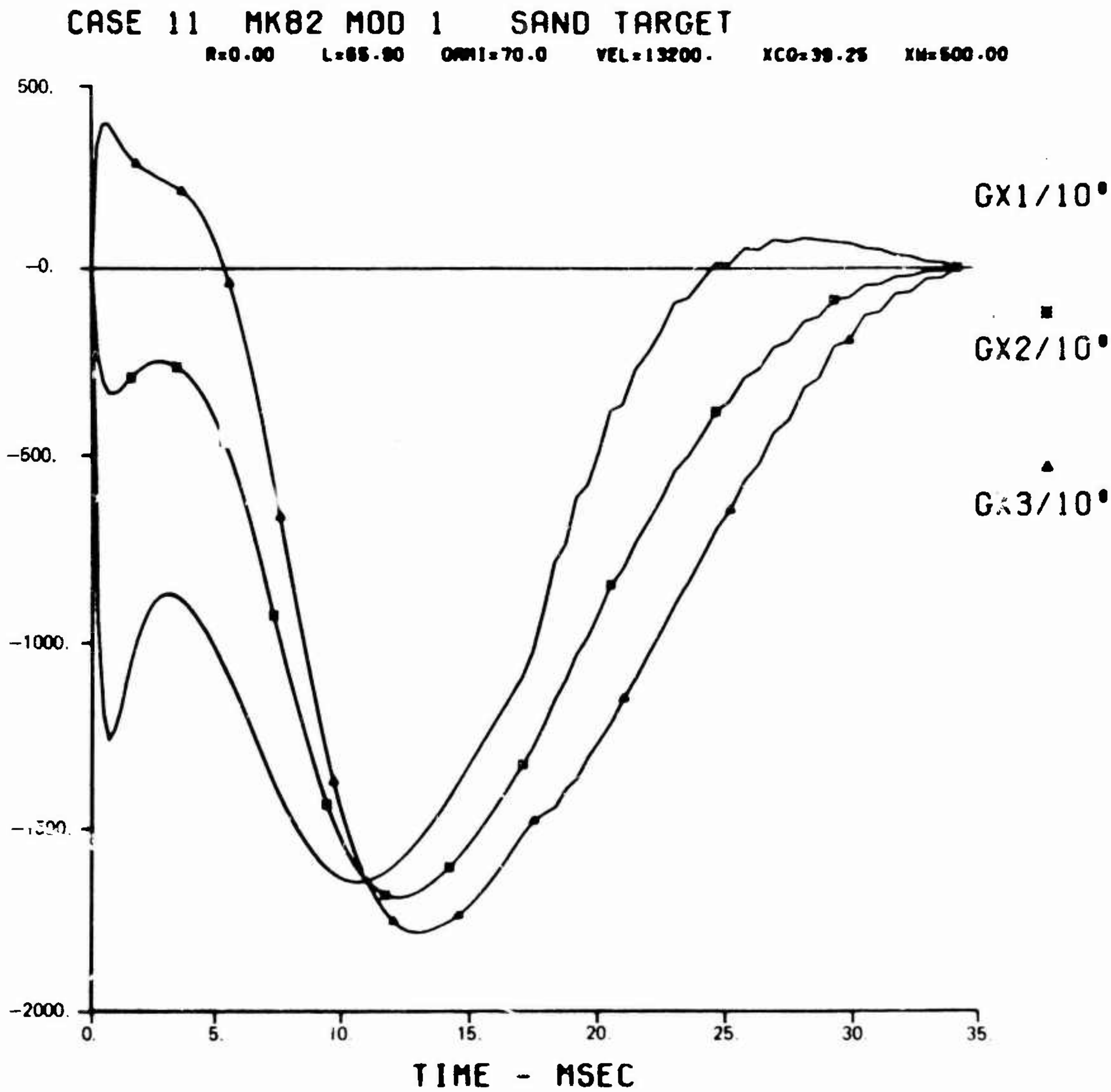

Figure 16 ACCELERATION ENVIRONMENT – LATERAL

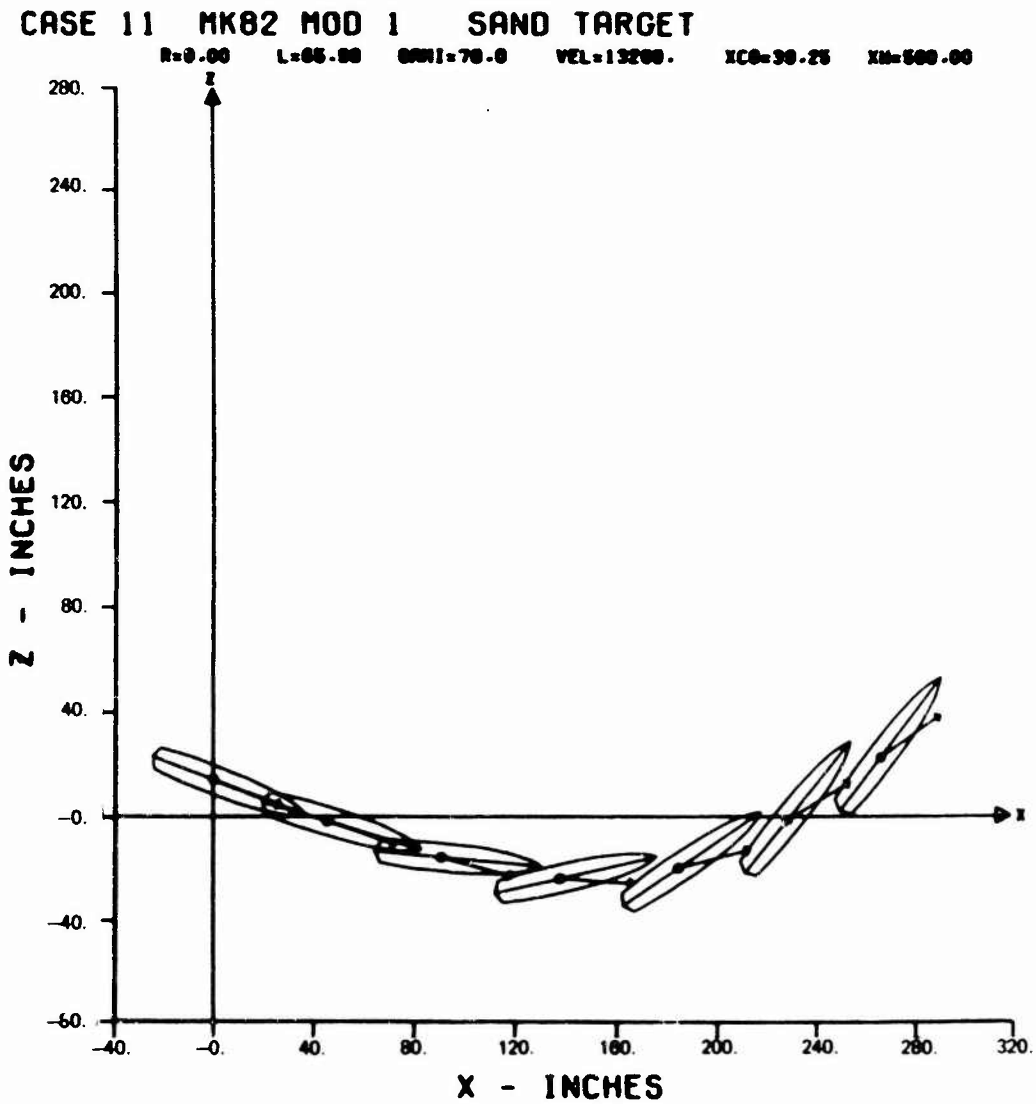

Figure 17 TRAJECTORY HISTORY

2.3 MK82 MATHEMATICAL MODEL

Generating a representative mathematical model of the MK82 bomb involved establishing an equivalent lumped parameter system of the MK82 which included the structure, filler material, and fuze systems. Two models were generated: an axial and a transverse system. These two models were to be analyzed independently in order to determine the orthogonal response motion of each. The system would have to be treated as coupled only if the amplitude of response were relatively large or the rotational rates were sufficiently high to effect the characteristics of the axial and bending stiffness. Neither is the case; consequently, the approach is valid.

The tasks to be accomplished in the generation of a representative dynamic system include:

1. Dividing the system into the appropriate number of elements for both the axial and transverse model.

2. Determining the mass and stiffness matrices for both systems.

3. Determining the eigen values, eigen vectors, and the modal damping matrices.

The basic layout of the MK82 bomb is shown in Figure 1. A complete set of detailed structural drawings was obtained for this configuration and from these drawings the number of degrees of freedom representing the axial and transverse models were selected.

The representative lumped parameter systems selected for this analysis are shown in Figures 18 and 19 for the axial and transverse models, respectively. Only a summary of the pertinent results are contained in this report.

Axial Model

The casing of the projectile is represented by Mass Sations 1 through 18 to be compatible with the 18 distributed load points generated by the 2-D Code. Mass Stations 19 through 24 represent the aft fuze and fuze support system. The fuze itself is No. 23. The forward fuze and structure is represented by Mass Stations 25 and 26, respectively. Connected to the aft end of the forward fuze and the aft fuze is the charging rod shown as Stations 40 through 42 and 37 through 39. The filler material includes Stations 27 through 36.

The mass and stiffness parameters from which the mass and stiffness matrices were developed are shown in Tables II and III. These were input to the contractor's Modal Analysis Program No. 2607 for the purpose of generating the eigen values, vectors, and damping matrices. The eigen values are listed in Table IV.

The eigen vectors were generated in graphical form and are presented in Appendix V.

The normalized modal damping matrix is given in Table V.

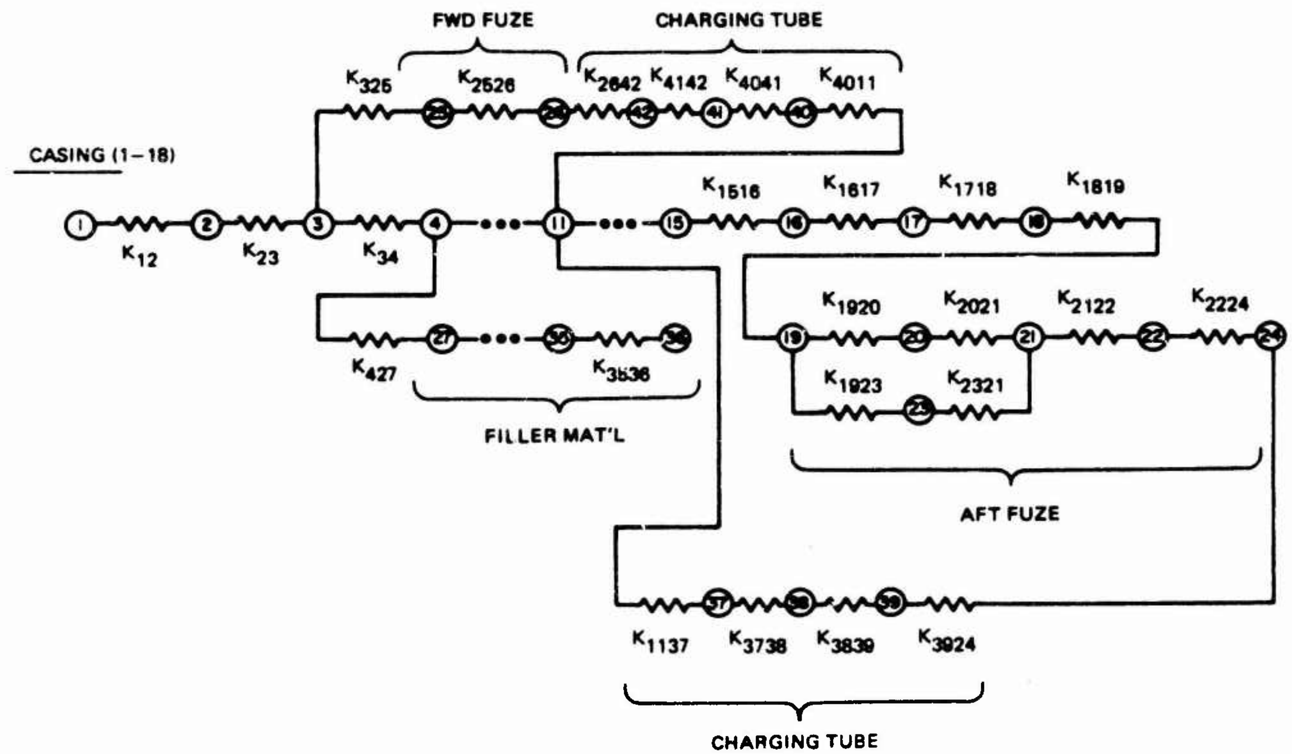

Figure 18 LUMPED PARAMETER SYSTEM – AXIAL MODEL

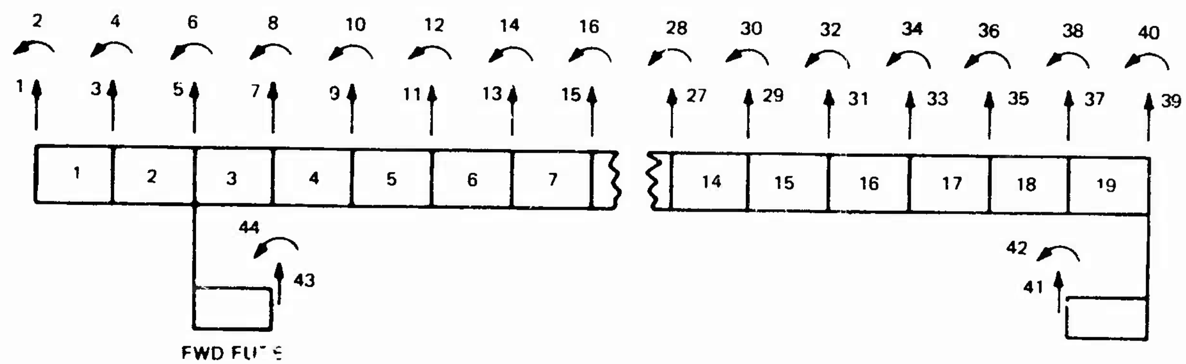

Figure 19 LUMPED PARAMETER SYSTEM – LATERAL MODEL

TABLE II. DISTRIBUTED MASS SUMMARY - AXIAL MODEL MK82 BOMB

1	0.00462	Lb-sec^2/in	22	0.00071	Lb-sec^2/in
2	0.02453		23	0.00112	
3	0.04485		24	0.01645	
4	0.03792		25	0.00071	
5	0.03452		26	0.01645	
6	0.03359		27	0.02324	
7	0.03748		28	0.03924	
8	0.03212		29	0.05068	
9	0.03164		30	0.05913	
10	0.03244		31	0.06196	
11	0.05470		32	0.06196	
12	0.04259		33	0.06196	
13	0.04259		34	0.06171	
14	0.04682		35	0.05827	
15	0.04039		36	0.07018	
16	0.03982		37	0.00026	
17	0.03858		38	0.00044	
18	0.05509		39	0.00059	
19	0.03242		40	0.00026	
20	0.00452		41	0.00044	
21	0.00209	Lb-sec^2/in	42	0.00059	Lb-sec^2/in

TABLE III. STIFFNESS SUMMARY - AXIAL MODEL

($\sim 10^6$ lbs/in)			
K12	53.27	K2123	426.242
K23	127.863	K325	57.520
K34	148.154	K2526	27.969
K45	126.416	K427	5.817
K56	124.100	K2728	7.899
K67	123.462	K2829	10.854
K78	119.417	K2930	13.463
K89	117.059	K3031	14.753
K910	115.798	K3132	14.994
K1011	108.196	K3233	14.994
K1112	95.642	K3334	14.994
K1213	95.642	K3435	14.633
K1314	95.642	K3536	11.219
K1415	89.798		
K1516	87.183	K1137	.00527
K1617	87.148	K3738	.00519
K1718	83.670	K3839	.00548
K1819	410.110	K3924	.288
K1920	10.256		
K2021	87.793	K1140	.00527
K2122	91.486	K4041	.00519
K2224	27.969	K4142	.00548
L1923	2.13	K4226	.228

TABLE IV. EIGEN VALUES - AXIAL MODEL

$(W_n)^2 \sim (\text{Rad/sec})^2$	$f_n \sim$ cps	$(W_n)^2 \sim (\text{Rad/sec})^2$	$f_n \sim$ cps
0	0	12.41232×10^8	5610
5.488218×10^6	373	18.20117×10^8	6793
14.75543×10^6	612	21.45058×10^8	7375
14.79315×10^6	612	29.07477×10^8	8586
40.54191×10^6	1014	38.31534×10^8	9857
49.46260×10^6	1120	47.35595×10^8	10958
49.46884×10^6	1120	49.62745×10^8	11218
76.16817×10^6	1390	57.09199×10^8	12032
1.24803×10^8	1779	66.62120×10^8	12997
2.25971×10^8	2394	74.72805×10^8	13765
2.612074×10^8	2574	82.13839×10^8	14432
3.627731×10^8	3033	87.00827×10^8	14853
4.093918×10^8	3222	1.063044×10^{10}	16417
4.928591×10^8	3535	1.259149×10^{10}	17867
5.122466×10^8	3604	1.373203×10^{10}	18660
5.460110×10^8	3721	1.562515×10^{10}	19905
6.602495×10^8	4092	2.101202×10^{10}	23082
7.531643×10^8	4370	4.630785×10^{10}	34266
7.92457×10^8	4433	18.79096×10^{10}	69026
8.916538×10^8	4755	62.43445×10^{10}	125821
9.496118×10^8	4907	76.40071×10^{10}	139184

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL

```
INPUT CARDS READ                                               10.23.55.51     10/27/72
DATA* B(  1,1)                                                                    *DATA
DATA*   9.536703D 02 -6.181507D 02 -1.510484D 02 -5.162837D 01 -2.470723D 01      *DATA
DATA*  -1.477146D 01 -1.111679D 01 -6.930945D 00 -5.172401D 00 -4.755606D 00      *DATA
DATA*  -5.510034D 00 -3.506832D 00 -2.962999D 00 -2.832428D 00 -2.173792D 00      *DATA
DATA*  -1.945810D 00 -1.748975D 00 -2.357346D 00 -1.379272D 00 -1.790[illegible]D-01      *DATA
DATA*  -8.222006D-02 -2.773832D-02 -4.407382D-02 -6.286824D-01 -2.273133D 00      *DATA
DATA*  -1.977080D 01 -5.534811D 00 -3.036852D 00 -2.016248D 00 -1.559516D 00      *DATA
DATA*  -1.242169D 00 -1.021651D 00 -8.874089D-01 -8.013064D-01 -7.[illegible]D-01      *DATA
DATA*  -8.186251D-01 -7.523849D-03 -8.839538D-03 -2.100962D-02 -8.629366D-03      *DATA
DATA*  -1.901191D-02 -2.618432D-01                                                *DATA
DATA* B(  2,1)                                                                    *DATA
DATA*  -6.181507D 02  3.685040D 03 -1.911760D 03 -3.703994D 02 -1.530045D 02      *DATA
DATA*  -8.[illegible]6204D 01 -6.271894D 01 -3.842495D 01 -2.835272D 01 -2.57[illegible]986D 01      *DATA
DATA*  -2.976830D 01 -1.686728D 01 -1.585484D 01 -1.516243D 01 -1.161894D 01      *DATA
DATA*  -1.038853D 01 -9.329966D 00 -1.256772D 01 -7.352890D 00 -9.537019D-01      *DATA
DATA*  -4.380381D-01 -1.477714D-01 -2.348096D-01 -3.348610D 00 -2.511098D 01      *DATA
DATA*  -1.306280D 02 -3.181[illegible]49D 01 -1.652104D 01 -1.081015D 01 -8.320442D 00      *DATA
DATA*  -6.613733D 00 -5.434094D 00 -4.717445D 00 -4.258383D 00 -3.771948D 00      *DATA
DATA*  -4.349187D 00 -4.010114D-02 -4.699405D-02 -1.116578D-01 -4.600568D-02      *DATA
DATA*  -1.019311D-01 -1.489787D 00                                                *DATA
DATA* B(  3,1)                                                                    *DATA
DATA*  -1.510484D 02 -1.911760D 03  7.306275D 03 -2.204366D 03 -4.515529D 02      *DATA
DATA*  -2.060902D 02 -1.359907D 02 -7.915168D 01 -5.655420D 01 -5.051363D 01      *DATA
DATA*  -5.703143D 01 -3.573918D 01 -2.987108D 01 -2.833318D 01 -2.152300D 01      *DATA
DATA*  -1.927426D 01 -1.727222D 01 -2.322849D 01 -1.358800D 01 -1.759718D 00      *DATA
DATA*  -8.081284D-01 -2.725806D-01 -4.331987D-01 -6.173969D 00 -1.076885D 03      *DATA
DATA*  -5.269029D 02 -7.452142D 01 -3.224411D 01 -2.029291D 01 -1.541044D 01      *DATA
DATA*  -1.218206D 01 -9.982176D 00 -8.652942D 00 -7.804395D 00 -6.909682D 00      *DATA
DATA*  -7.964840D 00 -7.407099D-02 -8.621408D-02 -2.060040D-01 -8.503716D-02      *DATA
DATA*  -1.914267D-01 -3.342401D 00                                                *DATA
DATA* B(  4,1)                                                                    *DATA
DATA*  -5.162837D 01 -3.703994D 02 -2.204366D 03  5.856262D 03 -1.795875D 03      *DATA
DATA*  -3.654081D 02 -1.807407D 02 -9.160141D 01 -6.014550D 01 -5.060917D 01      *DATA
DATA*  -5.458301D 01 -3.320267D 01 -2.717785D 01 -2.539381D 01 -1.917041D 01      *DATA
DATA*  -1.694969D 01 -1.510010D 01 -2.021934D 01 -1.182282D 01 -1.524844D 00      *DATA
DATA*  -6.999983D-01 -2.360154D-01 -3.752419D-01 -5.339009D 00 -2.894697D 01      *DATA
DATA*  -1.545664D 02 -1.568643D 02 -3.327156D 01 -1.643878D 01 -1.349322D 01      *DATA
DATA*  -1.050810D 01 -8.547615D 00 -7.375848D 00 -6.641110D 00 -5.872345D 00      *DATA
DATA*  -6.763878D 00 -6.438411D-02 -7.356455D-02 -1.776061D-01 -7.229338D-02      *DATA
DATA*  -1.453965D-01 -1.866122D 00                                                *DATA
DATA* B(  5,1)                                                                    *DATA
DATA*  -2.470723D 01 -1.530045D 02 -4.515529D 02 -1.795875D 03  5.306354D 03      *DATA
DATA*  -1.739836D 03 -3.804413D 02 -1.462701D 02 -8.255734D 01 -6.255851D 01      *DATA
DATA*  -6.245521D 01 -3.610060D 01 -2.850250D 01 -2.594105D 01 -1.921272D 01      *DATA
DATA*  -1.674352D 01 -1.476016D 01 -1.960573D 01 -1.145774D 01 -1.456782D 00      *DATA
DATA*  -6.728753D-01 -2.267072D-01 -3.607138D-01 -5.116584D 00 -6.855535D 00      *DATA
DATA*  -7.473086D 01 -5.438970D 01 -2.309363D 01 -1.466378D 01 -1.129088D 01      *DATA
DATA*  [illegible]211730D 00 -7.449573D 00 -6.454033D 00 -5.879522D 00 -5.218076D 00      *DATA
DATA*  -6.024626D [illegible] -[illegible]282360D-02 -6.866174D-02 -1.692586D-01 -6.830886D-02      *DATA
DATA*  -1.211999D-01 -1.213180D 00                                                *DATA
DATA* B(  6,1)                                                                    *DATA
DATA*  -1.477146D 01 -8.636204D 01 -2.060902D 02 -3.654081D 02 -1.739836D 03      *DATA
DATA*   5.207123D 03 -1.794993D 03 -3.235438D 02 -1.401790D 02 -9.115567D 01      *DATA
DATA*  -8.138329D 01 -6.394772D 01 -3.309990D 01 -2.911790D 01 -2.104328D 01      *DATA
DATA*  -1.800321D 01 -1.565840D 01 -2.055500D 01 -1.202182D 01 -1.524658D 00      *DATA
DATA*  -6.988112D-01 -2.352321D-01 -3.746326D-01 -5.253475D 00 -3.184714D 00      *DATA
DATA*  -4.593840D 01 -3.242746D 01 -1.820641D 01 -1.2[illegible]605D 01 -1.018034D 01      *DATA
DATA*  -8.316362D 00 -6.961231D 00 -6.120850D 00 -5.572460D 00 -4.952311D 00      *DATA
DATA*  -5.741946D 00 -6.541299D-02 -6.884037D-02 -1.738585D-01 -7.021588D-02      *DATA
DATA*  -1.094961D-01 -8.903564D-01                                                *DATA
DATA* B(  7,1)                                                                    *DATA
DATA*  -1.111579D 01 -6.271894D 01 -1.359907D 02 -1.807407D 02 -3.804413D 02      *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

```
DATA*  -1.794993D 03  5.374822D 03 -1.734763D 03 -3.543442D 02 -1.746263D 02        *DATA
DATA*  -1.317932D 02 -6.477178D 01 -4.583789D 01 -3.859409D 01 -2.734153D 01        *DATA
DATA*  -2.260662D 01 -1.933526D 01 -2.511413D 01 -1.464210D 01 -1.836025D 00        *DATA
DATA*  -8.406224D-01 -2.826560D-01 -4.506797D-01 -6.337979D 00 -2.116877D 00        *DATA
DATA*  -3.548535D 01 -2.551334D 01 -1.706060D 01 -1.276472D 01 -1.060435D 01        *DATA
DATA*  -8.811953D 00 -7.482164D 00 -6.630477D 00 -6.066856D 00 -5.419245D 00        *DATA
DATA*  -6.283293D 00 -8.020940D-02 -7.544582D-02 -2.064906D-01 -8.446516D-02        *DATA
DATA*  -1.148421D-01 -7.781667D-01                                                  *DATA
DATA* B(  8,1)                                                                      *DATA
DATA*  -6.930945D 00 -3.842495D 01 -7.915168D 01 -9.160141D 01 -1.452701D 02        *DATA
DATA*  -3.239438D 02 -1.734763D 03  4.985377D 03 -1.623386D 03 -3.521736D 02        *DATA
DATA*  -1.920131D 02 -8.087185D 01 -5.212734D 01 -4.122574D 01 -2.768157D 01        *DATA
DATA*  -2.243216D 01 -1.876167D 01 -2.396548D 01 -1.395001D 01 -1.724050D 00        *DATA
DATA*  -7.882700D-01 -2.646775D-01 -4.226350D-01 -5.907559D 00 -1.237216D 00        *DATA
DATA*  -2.257156D 01 -1.674248D 01 -1.261216D 01 -9.978590D 00 -8.535555D 00        *DATA
DATA*  -7.230552D 00 -6.191841D 00 -5.526095D 00 -5.079688D 00 -4.550344D 00        *DATA
DATA*  -5.285668D 00 -7.793605D-02 -7.084566D-02 -1.904792D-01 -6.067186D-02        *DATA
DATA*  -9.356858D-02 -5.394954D-01                                                  *DATA
DATA* B(  9,1)                                                                      *DATA
DATA*  -5.172401D 00 -2.835272D 01 -5.655420D 01 -6.014550D 01 -8.255734D 01        *DATA
DATA*  -1.401790D 02 -3.543442D 02 -1.623386D 03  4.920441D 03 -1.689485D 03        *DATA
DATA*  -3.993581D 02 -1.293611D 02 -7.282549D 01 -5.294152D 01 -3.355870D 01        *DATA
DATA*  -2.623120D 01 -2.133837D 01 -2.665722D 01 -1.550910D 01 -1.883881D 00        *DATA
DATA*  -8.599265D-01 -2.882476D-01 -4.610934D-01 -6.398092D 00 -8.865269D-01        *DATA
DATA*  -1.712211D 01 -1.315848D 01 -1.089183D 01 -9.038219D 00 -7.933937D 00        *DATA
DATA*  -6.824832D 00 -5.902324D 00 -5.302280D 00 -4.894785D 00 -4.396282D 00        *DATA
DATA*  -5.115555D 00 -9.139237D-02 -7.259617D-02 -2.038020D-01 -9.221420D-02        *DATA
DATA*  -8.847287D-02 -4.380172D-01                                                  *DATA
DATA* B( 10,1)                                                                      *DATA
DATA*  -4.765606D 00 -2.590986D 01 -5.051363D 01 -5.060917D 01 -6.255851D 01        *DATA
DATA*  -9.116567D 01 -1.746263D 02 -3.521736D 02 -1.689485D 03  5.229903D 03        *DATA
DATA*  -1.915330D 03 -3.033159D 02 -1.350049D 02 -8.667286D 01 -5.118652D 01        *DATA
DATA*  -3.792980D 01 -2.979184D 01 -3.631373D 01 -2.104242D 01 -2.503899D 00        *DATA
DATA*  -1.140680D 00 -3.815795D-01 -6.116898D-01 -8.413331D 00 -7.935829D-01        *DATA
DATA*  -1.599629D 01 -1.276379D 01 -1.144494D 01 -9.904547D 00 -8.878864D 00        *DATA
DATA*  -7.762276D 00 -6.773888D 00 -6.121027D 00 -5.673693D 00 -5.108282D 00        *DATA
DATA*  -5.953563D 00 -1.347984D-01 -9.083922D-02 -2.642369D-01 -1.359451D-01        *DATA
DATA*  -1.014650D-01 -4.333992D-01                                                  *DATA
DATA* B( 11,1)                                                                      *DATA
DATA*  -5.510034D 00 -2.976830D 01 -5.703143D 01 -5.458301D 01 -6.245521D 01        *DATA
DATA*  -8.138329D 01 -1.317932D 02 -1.920131D 02 -3.993581D 02 -1.915330D 03        *DATA
DATA*   5.650865D 03 -1.835720D 03 -4.009195D 02 -2.014534D 02 -1.051768D 02        *DATA
DATA*  -7.211886D 01 -5.375117D 01 -6.312356D 01 -3.644295D 01 -4.217730D 00        *DATA
DATA*  -1.916272D 00 -6.392695D-01 -1.027729D 00 -1.396733D 01 -8.975992D-01        *DATA
DATA*  -1.872240D 01 -1.554034D 01 -1.456442D 01 -1.345674D 01 -1.235370D 01        *DATA
DATA*  -1.091747D 01 -9.608839D 00 -8.733714D 00 -8.124603D 00 -7.331967D 00        *DATA
DATA*  -8.558297D 00 -3.315588D-01 -1.411805D-01 -4.307235D-01 -3.316965D-01        *DATA
DATA*  -1.454199D-01 -5.336597D-01                                                  *DATA
DATA* B( 12,1)                                                                      *DATA
DATA*  -3.506832D 00 -1.886728D 01 -3.573918D 01 -3.320267D 01 -3.610060D 01        *DATA
DATA*  -4.394772D 01 -6.477178D 01 -8.087185D 01 -1.293611D 02 -3.033159D 02        *DATA
DATA*  -1.835720D 03  5.170005D 03 -1.708727D 03 -3.725149D 02 -1.458131D 02        *DATA
DATA*  -8.547621D 01 -5.784714D 01 -6.330837D 01 -3.629932D 01 -4.013880D 00        *DATA
DATA*  -1.815536D 00 -6.029273D-01 -9.739062D-01 -1.297512D 01 -5.631941D-01        *DATA
DATA*  -1.202467D 01 -1.034927D 01 -1.055560D 01 -9.805542D 00 -9.173007D 00        *DATA
DATA*  -8.201863D 00 -7.274915D 00 -6.647160D 00 -6.205070D 00 -5.611850D 00        *DATA
DATA*  -6.559868D 00 -1.495603D-01 -1.119771D-01 -3.888587D-01 -1.492330D-01        *DATA
DATA*  -1.056936D-01 -3.562883D-01                                                  *DATA
DATA* B( 13,1)                                                                      *DATA
DATA*  -2.962999D 00 -1.589484D 01 -2.987108D 01 -2.717789D 01 -2.853250D 01        *DATA
DATA*  -3.309990D 01 -4.583789D 01 -5.212734D 01 -7.282549D 01 -1.350049D 02        *DATA
DATA*  -4.009195D 02 -1.708727D 03  5.143305D 03 -1.784249D 03 -3.267081D 02        *DATA
DATA*  -1.465055D 02 -8.587748D 01 -8.512552D 01 -4.832023D 01 -5.045225D 00        *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

```
DATA*  -2.269036D 00 -7.492143D-01 -1.217505D 00 -1.581117D 01 -4.711557D-01        *DATA
DATA*  -1.023087D 01 -9.093020D 00 -9.714928D 00 -9.268651D 00 -8.807670D 00        *DATA
DATA*  -7.952897D 00 -7.100528D 00 -6.516874D 00 -6.101513D 00 -5.528443D 00        *DATA
DATA*  -6.470321D 00 -1.176311D-01 -1.157579D-01 -4.579953D-01 -1.150582D-01        *DATA
DATA*  -9.981256D-02 -3.124771D-01                                                  *DATA
DATA* B( 14,1)                                                                      *DATA
DATA*  -2.832428D 00 -1.516243D 01 -2.833318D 01 -2.539381D 01 -2.594105D 01        *DATA
DATA*  -2.911790D 01 -3.859469D 01 -4.122574D 01 -5.294152D 01 -8.667286D 01        *DATA
DATA*  -2.014534D 02 -3.725149D 02 -1.784249D 03  5.244625D 03 -1.639467D 03        *DATA
DATA*  -3.543485D 02 -1.593358D 02 -1.344528D 02 -7.502898D 01 -7.246638D 00        *DATA
DATA*  -3.233571D 00 -1.059409D 00 -1.735707D 00 -2.176111D 01 -4.472055D-01        *DATA
DATA*  -9.832445D 00 -8.986254D 00 -9.967525D 00 -9.719093D 00 -9.355678D 00        *DATA
DATA*  -8.516670D 00 -7.645873D 00 -7.043764D 00 -6.611307D 00 -5.959749D 00        *DATA
DATA*  -7.029227D 00 -1.114742D-01 -1.332688D-01 -6.041780D-01 -1.071253D-01        *DATA
DATA*  -1.046209D-01 -3.075523D-01                                                  *DATA
DATA* B( 15,1)                                                                      *DATA
DATA*  -2.173792D 00 -1.161894D 01 -2.162300D 01 -1.917041D 01 -1.921272D 01        *DATA
DATA*  -2.104328D 01 -2.704153D 01 -2.768157D 01 -3.365870D 01 -5.118652D 01        *DATA
DATA*  -1.051768D 02 -1.458131D 02 -3.267081D 02 -1.689467D 03  4.825394D 03        *DATA
DATA*  -1.587671D 03 -3.204577D 02 -1.938189D 02 -1.041448D 02 -6.879440D 00        *DATA
DATA*  -3.911886D 00 -1.265973D 00 -2.101148D 00 -2.468718D 01 -3.414676D-01        *DATA
DATA*  -7.576966D 00 -7.093369D 00 -8.111647D 00 -8.053072D 00 -7.835973D 00        *DATA
DATA*  -7.182634D 00 -6.478265D 00 -5.987205D 00 -5.631663D 00 -5.117614D 00        *DATA
DATA*  -6.001101D 00 -8.719323D-02 -1.225634D-01 -6.506558D-01 -8.197118D-02        *DATA
DATA*  -8.666797D-02 -2.414782D-01                                                  *DATA
DATA* B( 16,1)                                                                      *DATA
DATA*  -1.945810D 00 -1.038853D 01 -1.927426D 01 -1.694969D 01 -1.674352D 01        *DATA
DATA*  -1.800321D 01 -2.260662D 01 -2.243216D 01 -2.623120D 01 -3.792980D 01        *DATA
DATA*  -7.211880D 01 -8.547621D 01 -1.465055D 02 -3.543485D 02 -1.537671D 03        *DATA
DATA*   4.734307D 03 -1.575198D 03 -3.958051D 02 -1.928508D 02 -1.354864D 01        *DATA
DATA*  -5.850461D 00 -1.858923D 00 -3.145791D 00 -3.414236D 01 -3.044955D-01        *DATA
DATA*  -6.803913D 00 -6.501178D 00 -7.620974D 00 -7.677897D 00 -7.537281D 00        *DATA
DATA*  -6.948127D 00 -6.290928D 00 -5.829619D 00 -5.493217D 00 -4.997416D 00        *DATA
DATA*  -5.864537D 00 -8.053866D-02 -1.307459D-01 -6.248079D-01 -7.379976D-02        *DATA
DATA*  -8.261640D-02 -2.200846D-01                                                  *DATA
DATA* B( 17,1)                                                                      *DATA
DATA*  -1.748975D 00 -9.329966D 00 -1.727222D 01 -1.510010D 01 -1.476016D 01        *DATA
DATA*  -1.565840D 01 -1.933526D 01 -1.876167D 01 -2.133637D 01 -2.975184D 01        *DATA
DATA*  -5.379117D 01 -5.784714D 01 -8.587748D 01 -1.593358D 02 -3.204577D 02        *DATA
DATA*  -1.575198D 03  4.661602D 03 -1.603681D 03 -4.823233D 02 -2.346828D 01        *DATA
DATA*  -9.760147D 00 -3.006868D 00 -5.261235D 00 -4.902307D 01 -2.729454D-01        *DATA
DATA*  -6.130109D 00 -5.953383D 00 -7.112844D 00 -7.247371D 00 -7.163326D 00        *DATA
DATA*  -6.632435D 00 -6.023107D 00 -5.593005D 00 -5.277580D 00 -4.805451D 00        *DATA
DATA*  -5.642556D 00 -7.509767D-02 -1.389813D-01 -1.060534D 00 -6.689568D-02        *DATA
DATA*  -7.797240D-02 -2.005238D-01                                                  *DATA
DATA* B( 18,1)                                                                      *DATA
DATA*  -2.357346D 00 -1.256772D 01 -2.322849D 01 -2.021934D 01 -1.950973D 01        *DATA
DATA*  -2.059500D 01 -2.511413D 01 -2.396548D 01 -2.669722D 01 -3.631373D 01        *DATA
DATA*  -6.312356D 01 -6.330837D 01 -8.512552D 01 -1.344528D 02 -1.938189D 02        *DATA
DATA*  -3.958051D 02 -1.603681D 03  7.598635D 03 -4.831739D 03 -8.411049D 01        *DATA
DATA*  -3.175687D 01 -9.174502D 00 -1.733417D 01 -1.166036D 02 -3.671481D-01        *DATA
DATA*  -8.277114D 00 -8.141900D 00 -9.870075D 00 -1.014380D 01 -1.007849D 01        *DATA
DATA*  -9.362893D 00 -8.522237D 00 -7.926246D 00 -7.487209D 00 -6.821997D 00        *DATA
DATA*  -8.013978D 00 -1.053752D-01 -2.220149D-01 -2.122082D 00 -9.091855D-02        *DATA
DATA*  -1.091200D-01 -2.730657D-01                                                  *DATA
DATA* B( 19,1)                                                                      *DATA
DATA*  -1.379272D 00 -7.352890D 00 -1.358800D 01 -1.182282D 01 -1.145774D 01        *DATA
DATA*  -1.202162D 01 -1.464210D 01 -1.395501D 01 -1.550910D 01 -2.104242D 01        *DATA
DATA*  -3.644295D 01 -3.629932D 01 -4.832023D 01 -7.502898D 01 -1.041448D 02        *DATA
DATA*  -1.928508D 02 -4.823233D 02 -4.831739D 03  6.345540D 03 -1.391259D 02        *DATA
DATA*  -3.759441D 01 -9.524413D 00 -2.466958D 01 -8.703197D 01 -2.147754D-01        *DATA
DATA*  -4.843730D 00 -4.770707D 00 -5.791656D 00 -5.957388D 00 -5.922125D 00        *DATA
DATA*  -5.503503D 00 -5.010531D 00 -4.660875D 00 -4.403191D 00 -4.012259D 00        *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

```
DATA*  -4.7135210 00 -6.2141780-02 -1.3478110-01 -1.3959400 00 -5.3245310-02       *DATA
DATA*  -6.4684400-02 -1.5992900-01                                                 *DATA
DATA* B( 20,1)                                                                     *DATA
DATA*  -1.7900090-01 -9.5370190-01 -1.7597180 00 -1.5248440 00 -1.4567820 00       *DATA
DATA*  -1.5246580 00 -1.8360250 00 -1.7240500 00 -1.8838810 00 -2.5038990 00       *DATA
DATA*  -4.2177300 00 -4.0138800 00 -5.0452250 00 -7.2466380 00 -8.8794400 00       *DATA
DATA*  -1.3548640 01 -2.3468280 01 -8.4110490 01 -1.3912590 02  1.1157140 03       *DATA
DATA*  -4.3633600 02 -5.9741150 01 -1.4321530 02 -1.6257800 02 -2.7820350-02       *DATA
DATA*  -6.2973440-01 -6.2975100-01 -7.7762610-01 -8.0837140-01 -8.0891540-01       *DATA
DATA*  -7.5503460-01 -6.8950850-01 -6.4277350-01 -6.0812380-01 -5.5464800-01       *DATA
DATA*  -6.5199580-01 -1.0177040-02 -4.1334920-02 -1.1586210 00 -7.0070900-03       *DATA
DATA*  -8.6927850-03 -2.0975090-02                                                 *DATA
DATA* B( 21,1)                                                                     *DATA
DATA*  -8.2220060-02 -4.3803810-01 -8.0812840-01 -6.9559830-01 -6.7287530-01       *DATA
DATA*  -6.9881120-01 -8.4062240-01 -7.8827000-01 -8.5992650-01 -1.1406800 00       *DATA
DATA*  -1.9162720 00 -1.8155360 00 -2.2690360 00 -3.2335710 00 -3.9118860 00       *DATA
DATA*  -5.6504610 00 -9.7601470 00 -3.1756870 01 -3.7594410 01 -4.3633600 02       *DATA
DATA*   1.8195490 03 -2.5277010 02 -8.8843140 02 -1.3269060 02 -1.2776390-02       *DATA
DATA*  -2.8930230-01 -2.8972600-01 -3.5832370-01 -3.7285420-01 -3.7333200-01       *DATA
DATA*  -3.4660460-01 -3.1844020-01 -2.9691480-01 -2.8094680-01 -2.5626330-01       *DATA
DATA*  -3.0125800-01 -4.7990290-03 -2.0567720-02 -6.4182820-01 -3.2229160-03       *DATA
DATA*  -4.0093370-03 -9.6459160-03                                                 *DATA
DATA* B( 22,1)                                                                     *DATA
DATA*  -2.7733320-02 -1.4777140-01 -2.7258060-01 -2.3601540-01 -2.2670720-01       *DATA
DATA*  -2.3523210-01 -2.8265600-01 -2.6467750-01 -2.8824760-01 -3.8157950-01       *DATA
DATA*  -6.3926950-01 -6.0292730-01 -7.4521430-01 -1.0594090 00 -1.2659730 00       *DATA
DATA*  -1.8589230 00 -3.0068680 00 -9.1745020 00 -9.5244130 00 -5.9741150 01       *DATA
DATA*  -2.5277010 02  5.6012400 02 -5.8568840 01 -1.5729860 02 -4.3095470-03       *DATA
DATA*  -9.7617770-02 -9.7907470-02 -1.2128910-01 -1.2633480-01 -1.2657690-01       *DATA
DATA*  -1.1824270-01 -1.0804290-01 -1.0076030-01 -9.5354770-02 -8.6584820-02       *DATA
DATA*  -1.0226370-01 -1.6637240-03 -7.6207610-03 -2.8000460-01 -1.0888630-03       *DATA
DATA*  -1.3584410-03 -3.2575900-03                                                 *DATA
DATA* B( 23,1)                                                                     *DATA
DATA*  -4.4073820-02 -2.3480960-01 -4.3319870-01 -3.7524190-01 -3.6071380-01       *DATA
DATA*  -3.7463260-01 -4.5067970-01 -4.2263900-01 -4.6109340-01 -6.1158980-01       *DATA
DATA*  -1.0277290 00 -9.7390620-01 -1.2175350 00 -1.7357070 00 -2.1011480 00       *DATA
DATA*  -3.1457510 00 -5.2612350 00 -1.7334170 01 -2.4669580 01 -1.4321530 02       *DATA
DATA*  -8.8643140 02 -5.8568840 01  1.2187340 03 -6.5025540 01 -6.8488040-03       *DATA
DATA*  -1.5507850-01 -1.5529540-01 -1.9265050-01 -1.9982960-01 -2.0068010-01       *DATA
DATA*  -1.6682450-01 -1.7065670-01 -1.5511940-01 -1.5056110-01 -1.3733250-01       *DATA
DATA*  -1.6144500-01 -2.5692880-03 -1.0582590-02 -3.3994170-01 -1.7275280-03       *DATA
DATA*  -2.1487900-03 -5.1704290-03                                                 *DATA
DATA* B( 24,1)                                                                     *DATA
DATA*  -6.2868240-01 -3.3486100 00 -6.1739650 00 -5.3390090 00 -5.1165840 00       *DATA
DATA*  -5.2934750 00 -6.3379790 00 -5.9075890 00 -6.3980920 00 -8.4133310 00       *DATA
DATA*   1.3967330 01 -1.2975120 01 -1.5811170 01 -2.1761110 01 -2.4887180 01       *DATA
DATA*  -3.4142360 01 -4.9023070 01 -1.1660060 02 -8.7031970 01 -1.6257800 02       *DATA
DATA*  -1.3269060 02 -1.5729860 02 -6.5025540 01  9.8713100 02 -9.7617790-02       *DATA
DATA*  -2.2137000 00 -2.2309670 00 -2.7782450 00 -2.9031780 00 -2.9145750 00       *DATA
DATA*  -2.7262770 00 -2.4934060 00 -2.3268470 00 -2.2029860 00 -2.0101780 00       *DATA
DATA*  -2.3637090 00 -4.1723780-02 -2.2602660-01 -1.2721500 01 -2.4792830-02       *DATA
DATA*  -3.1213460-02 -7.4078160-02                                                 *DATA
DATA* B( 25,1)                                                                     *DATA
DATA*  -2.2731330 00 -2.5110980 01 -1.0768850 03 -2.8946970 01 -6.8655350 00       *DATA
DATA*  -3.1847140 00 -2.1168770 00 -1.2372160 00 -8.8652690-01 -7.9358290-01       *DATA
DATA*  -8.9759920-01 -5.6319410-01 -4.7115570-01 -4.4720550-01 -3.4146760-01       *DATA
DATA*  -3.0449550-01 -2.7294540-01 -3.6714810-01 -2.1477540-01 -2.7820350-02       *DATA
DATA*  -1.2776390-02 -4.3095470-03 -6.8488040-03 -9.7617790-02  1.2247380 03       *DATA
DATA*  -6.9255650 01 -1.1525550 00 -5.0804840-01 -3.2015070-01 -2.4351920-01       *DATA
DATA*  -1.9264360-01 -1.5791440-01 -1.3691520-01 -1.2350370-01 -1.0935240-01       *DATA
DATA*  -1.2605660-01 -1.1709080-03 -1.3641230-03 -3.2576790-03 -1.3537690-03       *DATA
DATA*  -3.1800740-03 -7.1235630-02                                                 *DATA
DATA* B( 26,1)                                                                     *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

```
DATA*  -1.9770800D 01 -1.3062800D 02 -5.2690290D 02 -1.5455640D 02 -7.4730860D 01   *DATA
DATA*  -4.5938400D 01 -3.5485350D 01 -2.2571960D 01 -1.7122110D 01 -1.5996290D 01   *DATA
DATA*  -1.6722400D 01 -1.2024670D 01 -1.0230870D 01 -9.8324450D 00 -7.5769660D 00   *DATA
DATA*  -6.8039130D 00 -6.1301090D 00 -8.2771140D 00 -4.8437300D 00 -6.2973440D-01   *DATA
DATA*  -2.8930230D-01 -9.7617770D-02 -1.5507850D-01 -2.2137000D 00 -6.9255650D 01   *DATA
DATA*   1.2708020D 03 -1.7574470D 01 -1.0229650D 01 -6.9819340D 00 -5.4574930D 00   *DATA
DATA*  -4.3310860D 00 -3.6149760D 00 -3.1458170D 00 [illegible].8436730D 00 -2.5208410D 00   *DATA
DATA*  -2.9080420D 00 -2.6457820D-02 -3.1326690D-02 -7.4079880D-02 -3.4580890D-02   *DATA
DATA*  -1.3686010D-01 -1.0034610D 01                                                 *DATA
DATA* B( 27,1)                                                                       *DATA
DATA*  -5.5348110D 00 -3.1811490D 01 -7.4521420D 01 -1.5686430D 02 -5.4389700D 01   *DATA
DATA*  -3.2427460D 01 -2.5513340D 01 -1.6742480D 01 -1.3158480D 01 -1.2763790D 01   *DATA
DATA*  -1.5540340D 01 -1.0349270D 01 -9.0930200D 00 -8.9862540D 00 -7.0933690D 00   *DATA
DATA*  -6.5011780D 00 -5.9533830D 00 -8.1419000D 00 -4.7707070D 00 -6.2975100D-01   *DATA
DATA*  -2.8972600D-01 -9.7907470D-02 -1.5529540D-01 -2.2309670D 00 -1.1525550D 00   *DATA
DATA*  -1.7574470D 01  1.0775480D 03 -3.6340160D 02 -7.6041160D 01 -3.3373500D 01   *DATA
DATA*  -1.9220910D 01 -1.2534540D 01 -9.2404120D 00 -7.4542240D 00 -6.1437580D 00   *DATA
DATA*  -6.7493270D 00 -2.7320360D-02 -3.5117290D-02 -7.5720190D-02 -3.0185210D-02   *DATA
DATA*  -5.6488220D-02 -3.7639580D-01                                                 *DATA
DATA* B( 28,1)                                                                       *DATA
DATA*  -3.0368520D 00 -1.6521040D 01 -3.2344110D 01 -3.3271560D 01 -2.3093630D 01   *DATA
DATA*  -1.8206410D 01 -1.7060600D 01 -1.2612160D 01 -1.0891830D 01 -1.1444940D 01   *DATA
DATA*  -1.4964420D 01 -1.0555600D 01 -9.7149280D 00 -9.9675250D 00 -8.1116470D 00   *DATA
DATA*  -7.6209740D 00 -7.1128440D 00 -9.8700750D 00 -5.7916580D 00 -7.7762610D-01   *DATA
DATA*  -3.5832370D-01 -1.7128810D-01 -1.9205050D-01 -2.7782450D 00 -5.0804840D-01   *DATA
DATA*  -1.0229650D 01 -3.8340160D 02  1.5499990D 03 -5.9278760D 02 -1.3181670D 02   *DATA
DATA*  -5.9557090D 01 -3.4314200D 01 -2.3317140D 01 -1.7788630D 01 -1.4137890D 01   *DATA
DATA*  -1.5150180D 01 -3.5071380D-02 -4.6671930D-02 -9.5754570D-02 -3.8123210D-02   *DATA
DATA*  -6.8372500D-02 -2.8336020D-01                                                 *DATA
DATA* B( 29,1)                                                                       *DATA
DATA*  -2.0162480D 00 -1.0810150D 01 -2.0292910D 01 -1.6438780D 01 -1.4563780D 01   *DATA
DATA*  -1.2386050D 01 -1.2764720D 01 -9.9785900D 00 -9.0382190D 00 -9.9045470D 00   *DATA
DATA*  -1.3456740D 01 -9.8055420D 00 -9.2686510D 00 -9.7190930D 00 -8.0530720D 00   *DATA
DATA*  -7.6778970D 00 -7.2473710D 00 -1.0143800D 01 -5.9573880D 00 -8.0837140D-01   *DATA
DATA*  -3.7285420D-01 -1.2633480D-01 -1.9982960D-01 -2.9031760D 00 -3.2015070D-01   *DATA
DATA*  -6.9819340D 00 -7.6041160D 01 -5.9278760D 02  1.9677110D 03 -7.4817590D 02   *DATA
DATA*  -1.6122250D 02 -7.2774920D 01 -4.3626950D 01 -3.0911990D 01 -2.3514450D 01   *DATA
DATA*  -2.4496990D 01 -3.7737660D-02 -5.5211590D-02 -1.0105970D-01 -4.0501850D-02   *DATA
DATA*  -7.1022740D-02 -2.1704980D-01                                                 *DATA
DATA* B( 30,1)                                                                       *DATA
DATA*  -1.5595160D 00 -8.3204420D 00 -1.5410440D 01 -1.3453220D 01 -1.1290880D 01   *DATA
DATA*  -1.0180340D 01 -1.0604350D 01 -8.5355550D 00 -7.9339370D 00 -8.8968640D 00   *DATA
DATA*  -1.2353700D 01 -9.1730070D 00 -8.6076700D 00 -9.3556780D 00 -7.8359730D 00   *DATA
DATA*  -7.5372810D 00 -7.1633260D 00 -1.0076490D 01 -5.9721250D 00 -8.0591540D-01   *DATA
DATA*  -3.7333200D-01 -1.2657690D-01 -2.0609011D-01 -2.9145751D 00 -2.4351920D-01   *DATA
DATA*  -5.4674930D 00 -3.3873500D 01 -1.3181670D 02 -7.4817590D 02  2.5023270D 03   *DATA
DATA*  -8.2465780D 02 -1.7470280D 02 -8.1209670D 01 -5.0654550D 01 -3.5451790D 01   *DATA
DATA*  -3.5903330D 01 -3.6800490D-02 -5.6528970D-02 -1.0211260D-01 -4.1254770D-02   *DATA
DATA*  -7.1448340D-02 -1.7972390D-01                                                 *DATA
DATA* B( 31,1)                                                                       *DATA
DATA*  -1.2421690D 00 -6.6137330D 00 -1.2132060D 01 -1.0508100D 01 -9.0711730D 00   *DATA
DATA*  -8.3163620D 00 -8.8319530D 00 -7.2305520D 00 -6.6248320D 00 -7.7522760D 00   *DATA
DATA*  -1.0917470D 01 -8.2016300D 00 -7.9528970D 00 -8.5168700D 00 -7.1?26340D 00   *DATA
DATA*  -6.9481270D 00 -6.6324350D 00 -9.3628530D 00 -5.5035030D 00 -7.5?0340D-01   *DATA
DATA*  -3.4603460D-01 -1.1824270D-01 -1.6682450D-01 -2.7262770D 00 -1.9264360D-01   *DATA
DATA*  -4.3810660D 00 -1.9220910D 01 -5.5557090D 01 -1.6122250D 02 -8.2465780D 02   *DATA
DATA*   2.4246120D 03 -6.3448040D 02 -1.7625340D 02 -8.5346120D 01 -5.3378970D 01   *DATA
DATA*  -4.9569230D 01 -3.7010370D-02 -5.6975350D-02 -9.5938220D-02 -3.9059390D-02   *DATA
DATA*  -6.7143970D-02 -1.4832370D-01                                                 *DATA
DATA* B( 32,1)                                                                       *DATA
DATA*  -1.0216510D 00 -5.4340940D 00 -9.9821760D 00 -8.5476150D 00 -7.4499730D 00   *DATA
DATA*  -6.9612310D 00 -7.4821640D 00 -6.1518410D 00 -5.9023240D 00 -6.7738980D 00   *DATA
DATA*  -9.5603390D 00 -7.2749150D 00 -7.1065280D 00 -7.6456730D 00 -6.4782[illegible] 00   *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Cont'd)

```
DATA*  -6.290928D 00 -6.023107D 00 -8.522237D 00 -5.010531D 00 -6.895085D-01        *DATA
DATA*  -3.184402D-01 -1.080429D-01 -1.706567D-01 -2.493406D 00 -1.579144D-01        *DATA
DATA*  -3.614976D 00 -1.253454D 01 -3.421420D 01 -7.277492D 01 -1.747028D 02        *DATA
DATA*  -8.344804D 02  2.439893D 03 -8.335786D 02 -1.814201D 02 -8.735830D 01        *DATA
DATA*  -7.107517D 01 -3.438646D-02 -5.371628D-02 -8.802235D-02 -3.608234D-02        *DATA
DATA*  -6.173658D-02 -1.244973D-01                                                  *DATA
DATA* B( 33,1)                                                                      *DATA
DATA*  -8.874089D-01 -4.717445D 00 -8.652942D 00 -7.379848D 00 -6.494033D 00        *DATA
DATA*  -6.120850D 00 -6.630477D 00 -5.526095D 00 -5.302280D 00 -6.121927D 00        *DATA
DATA*  -8.733714D 00 -6.647160D 00 -6.516874D 00 -7.043764D 00 -5.987205D 00        *DATA
DATA*  -5.829619D 00 -5.593005D 00 -7.926246D 00 -4.660879D 00 -6.427735D-01        *DATA
DATA*  -2.969148D-01 -1.007603D-01 -1.591194D-01 -2.326847D 00 -1.359152D-01        *DATA
DATA*  -3.145817D 00 -9.240412D 00 -2.331714D 01 -4.362699D 01 -8.120967D 01        *DATA
DATA*  -1.782534D 02 -8.335786D 02  2.435991D 03 -8.418020D 02 -1.859015D 02        *DATA
DATA*  -1.151129D 02 -3.248970D-02 -5.128922D-02 -8.233030D-02 -3.394114D-02        *DATA
DATA*  -5.788599D-02 -1.094747D-01                                                  *DATA
DATA* B( 34,1)                                                                      *DATA
DATA*  -8.013064D-01 -4.258383D 00 -7.804395D 00 -6.641110D 00 -5.879522D 00        *DATA
DATA*  -5.572460D 00 -6.066856D 00 -5.079688D 00 -4.894785D 00 -5.673693D 00        *DATA
DATA*  -8.124603D 00 -6.205070D 00 -6.101513D 00 -6.611307D 00 -5.631663D 00        *DATA
DATA*  -5.493217D 00 -5.277580D 00 -7.487209D 00 -4.403191D 00 -6.081238D-01        *DATA
DATA*  -2.809468D-01 -9.535477D-02 -1.505611D-01 -2.202986D 00 -1.235037D-01        *DATA
DATA*  -2.843673D 00 -7.454224D 00 -1.778863D 01 -3.091199D 01 -5.065459D 01        *DATA
DATA*  -8.534612D 01 -1.814201D 02 -8.418020D 02  2.401240D 03 -8.411221D 02        *DATA
DATA*  -2.300816D 02 -3.104294D-02 -4.936251D-02 -7.807095D-02 -3.232499D-02        *DATA
DATA*  -5.501934D-02 -9.959142D-02                                                  *DATA
DATA* B( 35,1)                                                                      *DATA
DATA*  -7.098980D-01 -3.771948D 00 -6.909682D 00 -5.872345D 00 -5.218376D 00        *DATA
DATA*  -4.962311D 00 -5.419245D 00 -4.550344D 00 -4.396282D 00 -5.108282D 00        *DATA
DATA*  -7.331967D 00 -5.611850D 00 -5.528443D 00 -5.999749D 00 -5.117614D 00        *DATA
DATA*  -4.997416D 00 -4.805451D 00 -6.821997D 00 -4.012259D 00 -5.546480D-01        *DATA
DATA*  -2.562633D-01 -8.698482D-02 -1.373325D-01 -2.010178D 00 -1.093524D-01        *DATA
DATA*  -2.520841D 00 -6.143758D 00 -1.413789D 01 -2.351445D 01 -3.595179D 01        *DATA
DATA*  -5.337897D 01 -8.735830D 01 -1.859015D 02 -8.411221D 02  2.178003D 03        *DATA
DATA*  -8.273594D 02 -2.850191D-02 -4.553524D-02 -7.131072D-02 -2.961459D-02        *DATA
DATA*  -5.034466D-02 -8.861588D-02                                                  *DATA
DATA* B( 36,1)                                                                      *DATA
DATA*  -8.186251D-01 -4.349187D 00 -7.964840D 00 -6.763878D 00 -6.024626D 00        *DATA
DATA*  -5.741946D 00 -6.283293D 00 -5.285668D 00 -5.115555D 00 -5.953563D 00        *DATA
DATA*  -8.558297D 00 -6.555868D 00 -6.470321D 00 -7.029227D 00 -6.001101D 00        *DATA
DATA*  -5.864537D 00 -5.642556D 00 -8.013978D 00 -4.713521D 00 -6.519958D-01        *DATA
DATA*  -3.012580D-01 -1.022637D-01 -1.614450D-01 -2.363709D 00 -1.260566D-01        *DATA
DATA*  -2.908042D 00 -6.749327D 00 -1.515018D 01 -2.449699D 01 -3.590333D 01        *DATA
DATA*  -4.958923D 01 -7.107517D 01 -1.151129D 02 -2.300816D 02 -8.273594D 02        *DATA
DATA*   1.495656D 03 -3.366002D-02 -5.394752D-02 -8.391010D-02 -3.492118D-02        *DATA
DATA*  -5.931896D-02 -1.024696D-01                                                  *DATA
DATA* B( 37,1)                                                                      *DATA
DATA*  -7.523849D-03 -4.010114D-02 -7.407099D-02 -6.438411D-02 -6.228236D-02        *DATA
DATA*  -6.541299D-02 -8.020940D-02 -7.793605D-02 -9.039237D-02 -1.347984D-01        *DATA
DATA*  -3.315588D-01 -1.495603D-01 -1.176311D-01 -1.114742D-01 -8.719323D-02        *DATA
DATA*  -8.053866D-02 -7.509767D-02 -1.053752D-01 -6.214178D-02 -1.017704D-02        *DATA
DATA*  -4.799329D-03 -1.669724D-03 -2.545288D-03 -4.172378D-02 -1.170908D-03        *DATA
DATA*  -2.645782D-02 -2.732036D-02 -3.507138D-02 -3.773766D-02 -3.880649D-02        *DATA
DATA*  -3.701637D-02 -3.438646D-02 -3.248970D-02 -3.104294D-02 -2.850191D-02        *DATA
DATA*  -3.366002D-02  3.215316D 00 -9.545836D-01 -1.685774D-02 -3.131957D-04        *DATA
DATA*  -3.999724D-04 -8.835335D-04                                                  *DATA
DATA* B( 38,1)                                                                      *DATA
DATA*  -8.839538D-03 -4.699405D-02 -8.621408D-02 -7.356495D-02 -6.868174D-02        *DATA
DATA*  -6.884037D-02 -7.944582D-02 -7.084566D-02 -7.299617D-02 -9.083922D-02        *DATA
DATA*  -1.411869D-01 -1.119771D-01 -1.157579D-01 -1.332688D-01 -1.225634D-01        *DATA
DATA*  -1.307459D-01 -1.389813D-01 -2.220149D-01 -1.347811D-01 -4.133492D-02        *DATA
DATA*  -2.056772D-02 -7.620761D-03 -1.058259D-02 -2.260266D-01 -1.364123D-03        *DATA
DATA*  -3.132669D-02 -3.511729D-02 -4.887192D-02 -5.521159D-02 -5.852897D-02        *DATA
```

TABLE V. NORMALIZED MODAL DAMPING MATRIX-AXIAL MODEL (Concl'd)

```
DATA*  -5.697539D-02 -5.371628D-02 -5.128922D-02 -4.936251D-02 -4.553524D-02     *DATA
DATA*  -5.394752D-02 -9.545836D-01  4.135890D 00 -4.129261D-01 -3.988481D-04     *DATA
DATA*  -5.798696D-04 -1.088076D-03                                               *DATA
DATA* B( 39,1)                                                                   *DATA
DATA*  -2.100962D-02 -1.118578D-01 -2.060040D-01 -1.776061D-01 -1.692586D-01     *DATA
DATA*  -1.738985D-01 -2.064906D-01 -1.904792D-01 -2.038020D-01 -2.642369D-01     *DATA
DATA*  -4.307235D-01 -3.888587D-01 -4.579953D-01 -6.041780D-01 -6.506558D-01     *DATA
DATA*  -8.248079D-01 -1.060534D 00 -2.122082D 00 -1.399940D 00 -1.158621D 00     *DATA
DATA*  -6.418282D-01 -2.800046D-01 -3.399417D-01 -1.272150D 01 -3.257679D-03     *DATA
DATA*  -7.407988D-02 -7.572019D-02 -9.575457D-02 -1.010597D-01 -1.021126D-01     *DATA
DATA*  -9.593822D-02 -8.802235D-02 -8.233030D-02 -7.807095D-02 -7.131072D-02     *DATA
DATA*  -8.391010D-02 -1.685774D-02 -4.129261D-01  2.619209D 01 -8.414982D-04     *DATA
DATA*  -1.085560D-03 -2.496883D-03                                               *DATA
DATA* B( 40,1)                                                                   *DATA
DATA*  -8.629366D-03 -4.600568D-02 -8.503716D-02 -7.229338D-02 -6.830886D-02     *DATA
DATA*  -7.021588D-02 -8.446516D-02 -8.067186D-02 -9.221420D-02 -1.359451D-01     *DATA
DATA*  -3.316965D-01 -1.483330D-01 -1.150582D-01 -1.071253D-01 -8.197118D-02     *DATA
DATA*  -7.379976D-02 -6.639568D-02 -9.091855D-02 -5.324531D-02 -7.007090D-03     *DATA
DATA*  -3.222916D-03 -1.088863D-03 -1.727528D-03 -2.479283D-02 -1.353769D-03     *DATA
DATA*  -3.458989D-02 -3.018521D-02 -3.812321D-02 -4.050185D-02 -4.125477D-02     *DATA
DATA*  -3.905939D-02 -3.608234D-02 -3.394114D-02 -3.232499D-02 -2.961459D-02     *DATA
DATA*  -3.492118D-02 -3.131957D-04 -3.988481D-04 -8.414982D-04  3.215328D 00     *DATA
DATA*  -9.545292D-01 -1.662324D-02                                               *DATA
DATA* B( 41,1)                                                                   *DATA
DATA*  -1.901191D-02 -1.019311D-01 -1.914287D-01 -1.453965D-01 -1.211999D-01     *DATA
DATA*  -1.094961D-01 -1.148421D-01 -9.356858D-02 -8.847287D-02 -1.014850D-01     *DATA
DATA*  -1.454199D-01 -1.056936D-01 -9.981256D-02 -1.046209D-01 -8.666797D-02     *DATA
DATA*  -8.261640D-02 -7.797240D-02 -1.091200D-01 -6.408440D-02 -8.692785D-03     *DATA
DATA*  -4.009337D-03 -1.358441D-03 -2.148790D-03 -3.121346D-02 -3.180074D-03     *DATA
DATA*  -1.368601D-01 -5.648822D-02 -6.837250D-02 -7.102274D-02 -7.144834D-02     *DATA
DATA*  -6.714397D-02 -6.173058D-02 -5.788595D-02 -5.501934D-02 -5.034466D-02     *DATA
DATA*  -5.931896D-02 -3.999724D-04 -5.798696D-04 -1.085660D-03 -9.545292D-01     *DATA
DATA*   4.136203D 00 -4.105283D-01                                               *DATA
DATA* B( 42,1)                                                                   *DATA
DATA*  -2.618432D-01 -1.489787D 00 -3.342401D 00 -1.866122D 00 -1.213189D 00     *DATA
DATA*  -8.903564D-01 -7.781667D-01 -5.394954D-01 -4.380172D-01 -4.333992D-01     *DATA
DATA*  -5.336597D-01 -3.562883D-01 -3.124771D-01 -3.075523D-01 -2.414782D-01     *DATA
DATA*  -2.200846D-01 -2.005238D-01 -2.730657D-01 -1.599290D-01 -2.097909D-02     *DATA
DATA*  -9.645916D-03 -3.257590D-03 -5.170429D-03 -7.407816D-02 -7.123563D-02     *DATA
DATA*  -1.003461D 01 -3.763958D-01 -2.833602D-01 -2.170498D-01 -1.797239D-01     *DATA
DATA*  -1.483237D-01 -1.244973D-01 -1.094747D-01 -9.959142D-02 -8.861588D-02     *DATA
DATA*  -1.024696D-01 -8.835335D-04 -1.088076D-03 -2.496883D-03 -1.662324D-02     *DATA
DATA*  -4.105283D-01  2.623793D 01                                               *DATA
DATA*1                                                                           *DATA
```

The model representing the transverse bending characteristic of the MK82 is shown in Figure 19. The forward fuze is represented by Mass Stations 5 and 43, while the aft fuze is designated by Stations 39 and 41. Response information regarding average fuze accelerations can be obtained by averaging the accelerations of the two boundary stations. The mass and stiffness matrices for the lateral model are given in Tables VI and VII. This model was also analyzed to establish its dynamic characteristics, and the eigen values are presented in Table VIII.

The modal damping matrix is shown in Table IX.

TABLE VI. DISTRIBUTED MASS SUMMARY - LATERAL MODEL MK82 BOMB

1	0.000606	22	0.8575
2	0.000987	23	0.09459
3	0.0149	24	1.008
4	0.01876	25	0.09459
5	0.04393	26	1.008
6	0.23747	27	0.09963
7	0.05353	28	1.008
8	0.2629	29	0.09253
9	0.05187	30	1.009
10	0.31023	31	0.08811
11	0.05470	32	0.8880
12	0.3773	33	0.08273
13	0.05997	34	0.7785
14	0.4729	35	0.05808
15	0.06398	36	0.5024
16	0.5539	37	0.02781
17	0.06695	38	0.2641
18	0.6209	39	0.0669
19	0.06990	40	0.478
20	0.6812	41	0.00823
21	0.1000	42	0.1131
		43	0.00823
		44	0.1131

TABLE VII. STIFFNESS SUMMARY - LATERAL MODEL

K MATRIX

(1, 1)	0.10872232D 07	0.17449932D 07	-0.10872232D 07	0.17449932D 07
(2, 2)	0.45031908D 07	-0.17449932D 07	0.10932375D 07	0.0
(3, 3)	0.14879450D 08	0.20391531D 08	-0.13792227D 08	0.22135524D 08
(4, 4)	0.20268124D 09	-0.22135524D 08	-0.12711480D 09	0.0
(5, 5)	0.41410601D 09	0.28495217D 08	-0.27127911D 09	0.43540297D 08
(6, 6)	0.82128566D 09	-0.43540297D 08	-0.42302748D 09	0.0
(7, 7)	0.50954765D 08	-0.52981565D 07	-0.23826954D 09	0.38242100D 08
(8, 8)	0.13571486D 10	-0.38242100D 08	-0.63159962D 09	0.0
(9, 9)	0.43057537D 08	-0.73767579D 07	-0.15230743D 09	0.33965342D 08
(10, 10)	0.16733744D 10	-0.33965342D 08	-0.77306991D 09	0.0
(11, 11)	0.39677243D 08	0.11512905D 07	-0.24466500D 09	0.32816633D 08
(12, 12)	0.19712189D 10	-0.32816633D 08	-0.99674986D 09	0.0
(13, 13)	0.40513445D 08	0.32813126D 05	-0.20466945D 09	0.32849446D 08
(14, 14)	0.23553660D 10	-0.32849446D 08	-0.11788209D 10	0.0
(15, 15)	0.40350510D 08	-0.92632473D 06	-0.15983565D 09	0.31913122D 08
(16, 16)	0.26754579D 10	-0.31913122D 08	-0.12887421D 10	0.0
(17, 17)	0.39234277D 08	-0.85522958D 06	-0.19350712D 09	0.31057893D 08
(18, 18)	0.28633862D 10	-0.31057893D 08	-0.13725072D 10	0.0
(19, 19)	0.35284453D 08	0.93576242D 06	-0.15933742D 09	0.31993655D 08
(20, 20)	0.30775470D 10	-0.31993655D 08	-0.15025443D 10	0.0
(21, 21)	0.35743590D 08	0.10614675D 07	-0.15815848D 09	0.33055123D 08
(22, 22)	0.29253530D 10	-0.33055123D 08	-0.11819387D 10	0.0
(23, 23)	0.31631696D 08	0.0	-0.15515848D 09	0.33055123D 08
(24, 24)	0.26402183D 10	-0.33055123D 08	-0.11819387D 10	0.0
(25, 25)	0.31631696D 08	0.0	-0.15915848D 09	0.33055123D 08
(26, 26)	0.26402183D 10	-0.33055123D 08	-0.11819387D 10	0.0
(27, 27)	0.31631696D 08	0.0	-0.15515948D 09	0.33055123D 08
(28, 28)	0.26402133D 10	-0.33055123D 08	-0.11819387D 10	0.0
(29, 29)	0.30763579D 08	-0.18143655D 07	-0.14577731D 09	0.31240757D 08
(30, 30)	0.25232014D 10	-0.31240757D 08	-0.10725659D 10	0.0
(31, 31)	0.29393234D 08	-0.10705551D 07	-0.14435503D 09	0.30170202D 08
(32, 32)	0.22940523D 10	-0.30170202D 08	-0.96484955D 09	0.0
(33, 33)	0.28682500D 08	-0.39397955D 06	-0.13266986D 09	0.27775222D 08
(34, 34)	0.20578813D 10	-0.27774222D 08	-0.84265649D 09	0.0
(35, 35)	0.38019552D 08	-0.12491558D 07	-0.23772555D 09	0.23527057D 08
(36, 36)	0.23254871D 10	-0.28527047D 08	-0.12901000D 10	0.0
(37, 37)	0.11124557D 09	0.65506426D 08	-0.87473014D 08	0.94033492D 08
(38, 38)	0.30170239D 10	-0.94033492D 08	-0.22512961D 10	0.0
(39, 39)	0.87553475D 08	-0.95774177D 08	-0.52046352D 06	0.16915065D 07
(40, 40)	0.25137780D 10	+0.16915765D 07	-0.49325985D 08	
(41, 41)	0.52046352D 06	+0.16915065D 07		
(42, 42)	0.66320781D 08			

(5,43) -.52046352349809D 06 (5,44) .16915064513701D 07
(6,43) -.16915064513701D 07 (43,44) -.16915064513701D 07
(6,44) -.49325598869432D 08 (43,43) .52046352349[illegible] 06
(44,44) .66320780582337D 08

TABLE VIII. EIGEN VALUES - LATERAL MODEL

379	5216
808	5278
1160	5701
1184	6041
1275	6541
1717	6833
2161	7573
2518	8430
2831	9147
2971	9860
3226	10502
3374	10911
3581	11246
3639	12071
3764	12212
3802	12317
3949	13441
4185	14496
4214	15414
4667	17089
4759	21618

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL

```
INPUT CARDS READ                                                  12.23.12.43    10/25/72
DATA* B(  1,1)                                                                   *DATA
DATA*   4.260978D 01  3.493415D 01 -3.278321D 01  2.717586D 01 -7.953458D 00     *DATA
DATA*   2.537141D 01 -2.571362D 00  9.474192D 00 -6.967902D-01  5.272949D 00     *DATA
DATA*  -2.346231D-01  3.161051D 00 -4.047722D-02  2.173282D 00  4.480051D-02     *DATA
DATA*   1.497687D 00  7.493827D-02  1.025233D 00  7.916995D-02  7.050028D-01     *DATA
DATA*   1.103209D-01  5.817145D-01  1.220071D-01  4.157477D-01  1.334136D-01     *DATA
DATA*   2.636266D-01  1.521997D-01  1.781985D-01  1.561559D-01  1.316495D-01     *DATA
DATA*   1.647446D-01  9.235937D-02  1.727567D-01  7.016991D-02  1.354627D-01     *DATA
DATA*   4.219668D-02  6.591731D-02  2.186068D-02  1.796411D-01  3.955821D-02     *DATA
DATA*   1.655039D-02  9.849510D-03  5.702142D-02  3.906821D 00                   *DATA
DATA* B(  2,1)                                                                   *DATA
DATA*   3.493415D 01  1.254795D 02 -2.952668D 01  1.052852D 01 -3.350713D 00     *DATA
DATA*   5.391428D 00 -8.155096D-01  1.305233D 00 -2.688048D-01  5.015027D-01     *DATA
DATA*  -1.313569D-01  2.123409D-01 -8.456644D-02  1.075056D-01 -6.067709D-02     *DATA
DATA*   5.801884D-02 -4.503346D-02  3.367054D-02 -3.436095D-02  2.136541D-02     *DATA
DATA*  -3.708841D-02  1.736010D-02 -2.623522D-02  1.325445D-02 -2.063771D-02     *DATA
DATA*   9.314417D-03 -1.790017D-02  6.807965D-03 -1.433784D-02  5.102408D-03     *DATA
DATA*  -1.224949D-02  3.381721D-03 -1.065699D-02  2.276223D-03 -7.068556D-03     *DATA
DATA*   1.189263D-03 -3.285417D-03  5.744098D-04 -7.621839D-03  1.013940D-03     *DATA
DATA*  -1.011291D-03  2.003591D-04 -5.753316D-02  1.282450D-01                   *DATA
DATA* B(  3,1)                                                                   *DATA
DATA*  -3.278321D 01 -2.952668D 01  7.670271D 02  3.348749D 02 -5.774807D 02     *DATA
DATA*   8.508857D 02 -1.215942D 02  2.653311D 02 -3.541338D 01  1.394700D 02     *DATA
DATA*  -1.426435D 01  8.105278D 01 -6.281019D 00  5.485038D 01 -2.525321D 00     *DATA
DATA*   3.753661D 01 -7.502799D-01  2.568632D 01  3.657490D-02  1.774054D 01     *DATA
DATA*   7.143058D-01  1.473537D 01  1.614259D 00  1.065512D 01  2.210719D 00     *DATA
DATA*   6.845281D 00  2.829713D 00  4.677167D 00  3.117598D 00  3.473059D 00     *DATA
DATA*   3.440094D 00  2.433921D 00  3.721413D 00  1.838033D 00  3.007434D 00     *DATA
DATA*   1.097409D 00  1.557833D 00  5.665908D-01  4.043411D 00  1.024050D 00     *DATA
DATA*   3.573408D-01  2.523326D-01 -2.585315D 00  8.789148D 01                   *DATA
DATA* B(  4,1)                                                                   *DATA
DATA*   2.717586D 01  1.052852D 01  3.348749D 02  3.844703D 03 -2.770881D 02     *DATA
DATA*  -1.689067D 03 -4.543623D 01 -1.566656D 02 -1.564238D 01 -4.672236D 01     *DATA
DATA*  -6.914601D 00 -1.810916D 01 -4.038558D 00 -8.837001D 00 -2.562516D 00     *DATA
DATA*  -4.520174D 00 -1.688492D 00 -2.316322D 00 -1.143744D 00 -1.153714D 00     *DATA
DATA*  -1.102271D 00 -6.706834D-01 -7.251861D-01 -2.577089D-01 -5.299556D-01     *DATA
DATA*  -4.023892D-02 -4.294301D-01  4.062446D-02 -3.262686D-01  6.394908D-02     *DATA
DATA*  -2.666201D-01  5.720934D-02 -2.242375D-01  4.520605D-02 -1.452012D-01     *DATA
DATA*   2.582940D-02 -6.671609D-02  1.262911D-02 -1.538768D-01  2.277915D-02     *DATA
DATA*  -2.036477D-02  4.488966D-03 -3.546018D 00 -4.651851D 01                   *DATA
DATA* B(  5,1)                                                                   *DATA
DATA*  -7.953458D 00 -3.350713D 00 -5.774807D 02 -2.770881D 02  2.134819D 03     *DATA
DATA*   7.274799D 02 -1.171571D 03  1.171258D 03 -2.214638D 02  4.293881D 02     *DATA
DATA*  -8.462778D 01  2.308126D 02 -4.217738D 01  1.530531D 02 -2.251996D 01     *DATA
DATA*   1.048827D 02 -1.237234D 01  7.258523D 01 -6.593250D 00  5.096031D 01     *DATA
DATA*  -4.976922D 00  4.306435D 01  1.547705D-02  3.186617D 01  2.971039D 00     *DATA
DATA*   2.093264D 01  5.401261D 00  1.456005D 01  6.915097D 00  1.092380D 01     *DATA
DATA*   8.251341D 00  7.677648D 00  9.361167D 00  5.779018D 00  7.815069D 00     *DATA
DATA*   3.431070D 00  4.107930D 00  1.766168D 00  1.080243D 01  3.188586D 00     *DATA
DATA*   9.041585D-01  7.774953D-01 -3.922787D 01  1.540950D 02                   *DATA
DATA* B(  6,1)                                                                   *DATA
DATA*   2.537141D 01  5.391428D 00  8.508857D 02 -1.689067D 03  7.274799D 02     *DATA
DATA*   2.589117D 04 -9.665430D 02 -7.340343D 03 -2.620281D 02 -1.268767D 03     *DATA
DATA*  -1.092971D 02 -4.189942D 02 -6.191248D 01 -1.890336D 02 -3.829270D 01     *DATA
DATA*  -9.260715D 01 -2.466485D 01 -4.645782D 01 -1.634113D 01 -2.337298D 01     *DATA
DATA*  -1.540389D 01 -1.379634D 01 -1.000609D 01 -5.913118D 00 -7.207138D 00     *DATA
DATA*  -1.649859D 00 -5.756956D 00  2.853941D-02 -4.324062D 00  6.029756D-01     *DATA
DATA*  -3.497666D 00  6.562708D-01 -2.918342D 00  5.569422D-01 -1.879377D 00     *DATA
DATA*   3.287928D-01 -8.613484D-01  1.648454D-01 -1.985704D 00  2.932681D-01     *DATA
DATA*  -2.617402D-01  5.769283D-02 -7.055538D 01 -1.428479D 03                   *DATA
DATA* B(  7,1)                                                                   *DATA
DATA*  -2.571362D 00 -8.155096D-01 -1.215942D 02 -4.543623D 01 -1.171571D 03     *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

```
DATA*   -9.665430D 02  2.759290D 03 -3.598675D 01 -1.052762D 03  8.578274D 02          *DATA
DATA*   -2.167774D 02  3.051209D 02 -9.655781D 01  1.873813D 02 -5.158541D 01          *DATA
DATA*    1.266071D 02 -2.986361D 01  8.815635D 01 -1.822382D 01  6.274616D 01          *DATA
DATA*   -1.532331D 01  5.379635D 01 -5.953306D 00  4.056712D 01 -7.410884D-01          *DATA
DATA*    2.710349D 01  3.015727D 00  1.907830D 01  5.691389D 00  1.438459D 01          *DATA
DATA*    7.793258D 00  1.009599D 01  9.466618D 00  7.553259D 00  8.273675D 00          *DATA
DATA*    4.452767D 00  4.431252D 00  2.284403D 00  1.184680D 01  4.119399D 00          *DATA
DATA*    9.217223D-01  9.945024D-01 -2.712641D 01 -1.788498D 01                        *DATA
DATA* B( 8,1)                                                                          *DATA
DATA*    9.474192D 00  1.305233D 00  2.653311D 02 -1.566656D 02  1.171258D 03          *DATA
DATA*   -7.340343D 03 -3.598675D 01  3.564063D 04 -8.776924D 02 -1.039512D 04          *DATA
DATA*   -2.234328D 02 -1.576347D 03 -1.076712D 02 -5.420480D 02 -6.068837D 01          *DATA
DATA*   -2.308604D 02 -3.664693D 01 -1.070513D 02 -2.302812D 01 -5.161654D 01          *DATA
DATA*   -2.066721D 01 -3.007636D 01 -1.302862D 01 -1.350999D 01 -9.108254D 00          *DATA
DATA*   -4.681960D 00 -7.068319D 00 -1.140997D 00 -5.189663D 00  1.311074D-01          *DATA
DATA*   -4.115440D 00  5.776707D-01 -3.381131D 00  5.678848D-01 -2.153588D 00          *DATA
DATA*    3.719357D-01 -9.817588D-01  1.900754D-01 -2.259274D 00  3.396201D-01          *DATA
DATA*   -2.967337D-01  6.707765D-02 -1.265674D 01 -3.098539D 02                        *DATA
DATA* B( 9,1)                                                                          *DATA
DATA*   -6.967902D-01 -2.698048D-01 -3.541338D 01  1.564230D 01 -2.214638D 02          *DATA
DATA*   -2.620281D 02 -1.052762D 03 -8.776924D 02  2.596081D 03 -1.941684D 02          *DATA
DATA*   -8.971464D 02  6.745902D 02 -2.009687D 02  2.580096D 02 -8.941304D 01          *DATA
DATA*    1.545940D 02 -4.825101D 01  1.024723D 02 -2.876294D 01  7.121198D 01          *DATA
DATA*   -2.457179D 01  6.020219D 01 -1.156643D 01  4.498877D 01 -4.801629D 00          *DATA
DATA*    2.997310D 01 -3.582340D-01  2.687645D 01  4.019777D 00  1.558486D 01          *DATA
DATA*    5.458360D 00  1.080022D 01  7.437625D 00  7.969022D 00  6.878246D 00          *DATA
DATA*    4.643702D 00  3.772110D 00  2.371168D 00  1.029985D 01  4.259776D 00          *DATA
DATA*    7.231941D-01  1.020678D 00 -1.750387D 01 -2.722604D 01                        *DATA
DATA* B( 10,1)                                                                         *DATA
DATA*    5.272949D 00  5.015027D-01  1.394700D 02 -4.672236D 01  4.290881D 02          *DATA
DATA*   -1.268767D 03  8.578274D 02 -1.039512D 04 -1.941684D 02  4.265723D 04          *DATA
DATA*   -7.065305D 02 -1.182841D 04 -2.214574D 02 -1.982900D 03 -1.094913D 02          *DATA
DATA*   -6.717040D 02 -6.151094D 01 -2.794964D 02 -3.663746D 01 -1.276436D 02          *DATA
DATA*   -3.124027D 01 -7.270601D 01 -1.923911D 01 -3.333211D 01 -1.303110D 01          *DATA
DATA*   -1.277744D 01 -9.789538D 00 -4.452110D 00 -6.996981D 00 -1.138395D 00          *DATA
DATA*   -5.408221D 00  1.780416D-01 -4.351600D 00  5.262244D-01 -2.732921D 00          *DATA
DATA*    4.050366D-01 -1.238139D 00  2.169674D-01 -2.853629D 00  3.912690D-01          *DATA
DATA*   -3.069180D-01  7.684544D-02 -2.578027D 00 -1.361879D 02                        *DATA
DATA* B( 11,1)                                                                         *DATA
DATA*   -2.346251D-01 -1.313569D-01 -1.426435D 01 -6.914601D 00 -8.452778D 01          *DATA
DATA*   -1.092971D 02 -2.167774D 02 -2.234328D 02 -8.971464D 02 -7.095305D 02          *DATA
DATA*    2.583320D 03  3.981161D 01 -9.732759D 02  7.908206D 02 -2.077006D 02          *DATA
DATA*    2.945598D 02 -8.919811D 01  1.675505D 02 -4.786285D 01  1.071373D 02          *DATA
DATA*   -3.898292D 01  8.559394D 01 -1.902735D 01  6.113715D 01 -9.455258D 00          *DATA
DATA*    3.920146D 01 -3.747845D 00  2.658673D 01  6.689220D-01  1.931168D 01          *DATA
DATA*    3.743795D 00  1.303494D 01  6.112393D 00  9.391157D 00  6.141236D 00          *DATA
DATA*    5.374981D 00  3.473020D 00  2.725908D 00  9.751822D 00  4.899042D 00          *DATA
DATA*    5.870916D-01  1.158402D 00 -1.201681D 01 -1.[illegible]356370 01              *DATA
DATA* B( 12,1)                                                                         *DATA
DATA*    3.151051D 00  2.123409D-01  8.109278D 01 -1.810916D 01  2.308126D 02          *DATA
DATA*   -4.189142D 02  3.051209D 02 -1.576347D 03  6.745902D 02 -1.182841D 04          *DATA
DATA*    3.981161D 01  5.090848D 04 -7.566563D 02 -1.565096D 04 -2.398964D 02          *DATA
DATA*   -2.602112D 03 -1.168184D 02 -8.671522D 02 -6.583762D 01 -3.576834D 02          *DATA
DATA*   -5.277089D 01 -1.935009D 02 -3.180704D 01 -8.761186D 01 -2.084856D 01          *DATA
DATA*   -3.486335D 01 -1.569634D 01 -1.371894D 01 -1.045643D 01 -5.114671D 00          *DATA
DATA*   -7.325296D 00 -1.236617D 00 -6.126186D 00  9.351947D-02 -3.778968D 00          *DATA
DATA*    4.434135D-01 -1.695596D 00  2.130484D-01 -3.943017D 00  3.946990D-01          *DATA
DATA*   -4.836382D-01  7.591911D-02  1.455486D 00 -6.724796D 01                        *DATA
DATA* B( 13,1)                                                                         *DATA
DATA*   -4.047722D-02 -8.458644D-02 -6.281015D 00 -4.035558D 00 -4.217738D 01          *DATA
DATA*   -6.[illegible]12480 01 -[illegible] 01  [illegible]036712 02 -[illegible]009687D 02 -2.[illegible]16574 02   *DATA
DATA*   -[illegible]732759D 02 -7.[illegible] 02  2.742149D 03 -1.007734D 01 -1.108931D 03          *DATA
DATA*    7.966619D 02 -2.[illegible] 02  [illegible] 02 -[illegible] 01  1.[illegible] 02          *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

```
DATA*  -6.680127D 01  1.235815D 02 -3.208643D 01  8.477037D 01 -1.599941D 01        *DATA
DATA*   5.296712D 01 -8.821205D 00  3.515336D 01 -2.527687D 00  2.507715D 01        *DATA
DATA*   1.546464D 00  1.651982D 01  4.616787D 00  1.165296D 01  5.432213D 00        *DATA
DATA*   6.556168D 00  3.226812D 00  3.302152D 00  9.441253D 00  5.922433D 00        *DATA
DATA*   4.384197D-01  1.382734D 00 -8.953711D 00 -1.475960D 01                      *DATA
DATA* B( 14,1)                                                                      *DATA
DATA*   2.173282D 00  1.075056D-01  5.465038D 01 -8.837001D 00  1.530531D 02        *DATA
DATA*  -1.890336D 02  1.873813D 02 -5.420480D 02  2.560096D 02 -1.982900D 03        *DATA
DATA*   7.908206D 02 -1.565096D 04 -1.007234D 01  6.221068D 04 -7.967364D 02        *DATA
DATA*  -1.904975D 04 -2.570218D 02 -3.138596D 03 -1.259428D 02 -1.042040D 03        *DATA
DATA*  -9.324275D 01 -5.082253D 02 -5.501084D 01 -2.184269D 02 -3.493630D 01        *DATA
DATA*  -8.617403D 01 -2.445637D 01 -3.505014D 01 -1.647293D 01 -1.44127  D 01        *DATA
DATA*  -1.196456D 01 -4.732920D 00 -9.125874D 00 -1.147843D 00 -5.538182D 00        *DATA
DATA*   4.132598D-02 -2.475724D 00  1.227264D-01 -5.807634D 00  2.577902D-01        *DATA
DATA*  -6.676841D-01  4.443162D-02  3.183934D 00 -3.883778D 01                      *DATA
DATA* B( 15,1)                                                                      *DATA
DATA*   4.480051D-02 -6.067709D-02 -2.525321D 00 -2.562516D 00 -2.251996D 01        *DATA
DATA*  -3.829270D 01 -5.168541D 01 -6.068837D 01 -8.941304D 01 -1.094913D 02        *DATA
DATA*  -2.077006D 02 -2.398964D 02 -1.008931D 03 -7.967364D 02  2.822523D 03        *DATA
DATA*  -4.129354D 01 -1.013427D 03  7.857569D 02 -2.107635D 02  2.822542D 02        *DATA
DATA*  -1.211935D 02  1.866133D 02 -5.358118D 01  1.197454D 02 -2.827078D 01        *DATA
DATA*   7.211114D 01 -1.598684D 01  4.659466D 01 -6.972075D 00  3.237405D 01        *DATA
DATA*  -1.504807D 00  2.089544D 01  2.459304D 00  1.440646D 01  4.309882D 00        *DATA
DATA*   7.952596D 00  2.792606D 00  3.973685D 00  8.720188D 00  7.109185D 00        *DATA
DATA*   2.309020D-01  1.634158D 00 -6.605378D 00 -1.104063D 01                      *DATA
DATA* B( 16,1)                                                                      *DATA
DATA*   1.497687D 00  5.801884D-02  3.753661D 01 -4.520174D 00  1.048827D 02        *DATA
DATA*  -9.260715D 01  1.266071D 02 -2.308604D 02  1.545940D 02 -6.717040D 02        *DATA
DATA*   2.545698D 02 -2.602122D 03  7.966619D 02 -1.904975D 04 -4.129354D 01        *DATA
DATA*   7.113457D 04 -8.000184D 02 -2.136030D 04 -2.541331D 02 -3.488224D 03        *DATA
DATA*  -1.622207D 02 -1.352828D 03 -9.230681D 01 -5.198519D 02 -5.628962D 01        *DATA
DATA*  -1.957605D 02 -3.797637D 01 -7.911721D 01 -2.488219D 01 -3.357927D 01        *DATA
DATA*  -1.755194D 01 -1.218989D 01 -1.305244D 01 -4.050558D 00 -7.804044D 00        *DATA
DATA*  -8.277458D-01 -3.471135D 00 -1.922263D-01 -8.272666D 00 -2.539483D-01        *DATA
DATA*  -8.750347D-01 -5.513297D-02  3.798254D 00 -2.258753D 01                      *DATA
DATA* B( 17,1)                                                                      *DATA
DATA*   7.493827D-02 -4.503346D-02 -7.502795D-01 -1.688492D 00 -1.237234D 01        *DATA
DATA*  -2.466485D 01 -2.986361D 01 -3.664693D 01 -4.825101D 01 -6.154694D 01        *DATA
DATA*  -8.919811D 01 -1.188184D 02 -2.121970D 02 -2.570218D 02 -1.013427D 03        *DATA
DATA*  -8.000184D 02  2.859354D 03 -3.576895D 01 -1.007591D 03  7.861633D 02        *DATA
DATA*  -2.667350D 02  3.252829D 02 -9.491585D 01  1.815453D 02 -4.653544D 01        *DATA
DATA*   1.026344D 02 -2.644439D 01  6.373227D 01 -1.307191D 01  4.291851D 01        *DATA
DATA*  -5.552865D 00  2.692640D 01 -3.773550D-01  1.806822D 01  2.809646D 00        *DATA
DATA*   9.749608D 00  2.197677D 00  4.623890D 00  7.691833D 00  6.603053D 00        *DATA
DATA*  -3.325492D-02  1.938869D 00 -4.811527D 00 -8.112236D 00                      *DATA
DATA* B( 18,1)                                                                      *DATA
DATA*   1.025233D 00  3.367054D-02  2.568632D 01 -2.316322D 00  7.256523D 01        *DATA
DATA*  -4.649782D 01  8.815635D 01 -1.070513D 02  1.024723D 02 -2.774964D 02        *DATA
DATA*   1.675555D 02 -8.671522D 02  2.857329D 02 -3.138596D 03  7.857569D 02        *DATA
DATA*  -2.136030D 04 -3.576895D 01  7.790297D 04 -7.776567D 02 -2.314831D 04        *DATA
DATA*  -3.053683D 02 -4.316990D 03 -1.590916D 02 -1.304201D 03 -9.087042D 01        *DATA
DATA*  -4.440345D 02 -5.848425D 01 -1.722157D 02 -3.716243D 01 -7.281430D 01        *DATA
DATA*  -2.542881D 01 -2.744627D 01 -1.843150D 01 -1.011671D 01 -1.096876D 01        *DATA
DATA*  -2.792081D 00 -4.813490D 00 -9.388802D-01 -1.171548D 01 -1.482703D 00        *DATA
DATA*  -1.116256D 00 -2.885304D-01  3.806220D 00 -1.290828D 01                      *DATA
DATA* B( 19,1)                                                                      *DATA
DATA*   7.916955D-02 -3.436095D-02  3.657490D-02 -1.143744D 00 -6.993250D 00        *DATA
DATA*  -1.634113D 01 -1.822382D 01 -2.302812D 01 -2.876294D 01 -3.663746D 01        *DATA
DATA*  -4.786285D 01 -6.583762D 01 -9.123108D 01 -1.259428D 02 -2.107635D 02        *DATA
DATA*  -2.541331D 02 -1.007591D 03 -7.776567D 02  2.949744D 03  2.857636D 01        *DATA
DATA*  -1.176233D 03  8.974476D 02 -2.038264D 02  4.172672D 02 -8.298377D 01        *DATA
DATA*   1.586437D 02 -4.370785D 01  9.257520D 01 -2.217941D 01  5.974412D 01        *DATA
DATA*  -1.118664D 01  3.619512D 01 -4.139045D 00  2.352158D 01  8.863187D-01        *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

```
DATA*    1.[illegible]353520 01  1.447[illegible] [illegible]  6.038317D 00  6.456841D 00  1.072531D 01     *DATA
DATA*   -1.[illegible]544790-01  2.356776D [illegible] -3.455785D 00 -5.929870D 00                       *DATA
DATA* B( 20,1)                                                                                 *DATA
DATA*    7.0[illegible]0028D-01  2.138541D [illegible]  1.774054D 01 -1.163714D 00  5.096031D 01         *DATA
DATA*   -2.337298D 01  6.274616D 01 -5.161654D 01  7.171198D 01 -1.276436D 02                  *DATA
DATA*    1.071373D 02 -3.576834D 02  1.640266D 02 -1.042040D 03  2.822542D 02                  *DATA
DATA*   -3.488224D 03  7.861533D 02 -2.314831D 04  2.857636D 01  8.[illegible]58613D 04          *DATA
DATA*   -8.653464D 02 -2.711288D 04 -1.057323D 02 -3.908180D 03 -1.527422D 02                  *DATA
DATA*   -1.077072D 03 -9.168046D 01 -3.757929D 02 -5.608375D 01 -1.548263D 02                  *DATA
DATA*   -3.711145D 01 -5.84681[illegible] 01 -2.619315D 01 -2.261154D 01 -1.524413D 01           *DATA
DATA*   -6.653996D 00 -6.723[illegible] 00 -2.499811D 00 -1.679280D 01 -4.052946D 00             *DATA
DATA*   -1.411978D 00 -7.569117D-01  3.535978D 00 -7.211507D 00                                *DATA
DATA* B( 21,1)                                                                                 *DATA
DATA*    1.103209D-01 -3.708841D-02  7.143058D-01 -1.102271D 00 -4.976922D 00                  *DATA
DATA*   -1.540389D 01 -1.532331D 01 -[illegible].066721D 01 -2.457179D 01 -3.124027D 01          *DATA
DATA*   -3.698252D 01 -5.277[illegible] 01 -6.[illegible] 01 -9.324275D 01 -1.211935D 02          *DATA
DATA*   -1.622207D 02 -2.667350D 02 -3.053688D 02 -1.176233D 03 -8.653464D 02                  *DATA
DATA*    3.247301D 03 -4.215223D 03 -1.103504D 03  1.694208D 03 -2.339113D 02                  *DATA
DATA*    3.647111D 02 -1.04894[illegible] 02  [illegible].914543D 02 -5.119012D 01  1.171087D 02  *DATA
DATA*   -2.714782D 01  6.837210D 01 -1.313912D 01  4.303231D 01 -2.493776D 00                  *DATA
DATA*    2.193426D 01  5.482631D-01  1.060343D 01  6.479889D 00  1.874432D 01                  *DATA
DATA*   -1.055295D 00  3.992637D [illegible] -3.455951D 00 -6.061544D 00                         *DATA
DATA* B( 22,1)                                                                                 *DATA
DATA*    5.817145D-01  1.736[illegible]  1.477537D 01 -6.706834D-01  4.306435D 01                *DATA
DATA*   -1.379534D 01  5.379[illegible] -3.[illegible] 01  6.020219D 01 -7.270601D 01             *DATA
DATA*    8.569394D 01 -[illegible]935009D [illegible]  1.235815D 02 -5.082253D 02  1.866133D 02   *DATA
DATA*   -1.355828D 03  3.252[illegible] -4.316995D 03  8.974476D 02 -2.711288D 04                *DATA
DATA*   -4.215223D 00  7.234643D [illegible] -1.023486D 03 -2.465052D 04 -3.237697D 02           *DATA
DATA*   -3.465353D 03 -1.713795D [illegible] -1.013487D 03 -9.934921D 01 -3.811526D 02           *DATA
DATA*   -6.319323D 01 -1.398131D 02 -4.334238D 01 -5.433598D 01 -2.489416D 01                  *DATA
DATA*   -1.70[illegible] 01 -1.092531D 01 -6.379035D 00 -2.810585D 01 -1.040071D 01              *DATA
DATA*   -2.053275D 00 -1.870[illegible] 00  3.716627D 00 -4.675211D 00                           *DATA
DATA* B( 23,1)                                                                                 *DATA
DATA*    1.22[illegible]71D-01 -2.6235[illegible]-02  1.[illegible] 00 -7.[illegible]18610-01  1.547705D-02  *DATA
DATA*   -1.000503D 01 -5.955336D 00 -1.[illegible] 01 -1.158643D 01 -1.923911D 01                *DATA
DATA*   -1.962775D 01 -3.190764D 01 -[illegible] 01 -5.501084D 01 -5.358118D 01                  *DATA
DATA*   -9.230531D 01 -9.441595D 01 -[illegible] -2.036264D 02 -3.057321D 02                     *DATA
DATA*   -1.103504  03 -1.02348[illegible] 03  3.0[illegible] 03 -1.[illegible]3772D 01 -1.033720D 03  *DATA
DATA*    1.088417D 03 -1.370795D 02  [illegible]5427741 02 -9.535541D 01  1.901767D 02           *DATA
DATA*   -4.834740D 01  1.025499D 02 -2.5564[illegible] 01  6.081776D 01 -8.723447D 00             *DATA
DATA*    2.960567D 01 -1.378564D 00  1.394[illegible] 01  1.897276D 00  2.442899D 01              *DATA
DATA*   -1.945772D 00  4.[illegible] 00 -1.564485D 00 -4.201503D 00                              *DATA
DATA* B( 24,1)                                                                                 *DATA
DATA*    4.157477D-01  1.[illegible]25446D-02  1.065512D 01 -2.577089D-01  3.186617D 01           *DATA
DATA*   -5.913118D 00  4.05671[illegible] 01 -1.350955D 01  4.498877D 01 -3.333211D 01            *DATA
DATA*    6.113715D 01 -8.[illegible]118[illegible] 01  5.477037D 01 -2.184269D 02  1.197454D 02   *DATA
DATA*   -5.198519D 02  1.815458D [illegible] -1.304[illegible]01D 03  3.172672D 02 -3.908180D 03  *DATA
DATA*    1.094206D 03 -2.46505[illegible] 04 -1.88838[illegible] 01  9.583216D 04 -1.100725D 03   *DATA
DATA*   -2.559125D 04 -3.740[illegible] 02 -3.815456[illegible] 01 -1.931482D 02 -1.156891D 03    *DATA
DATA*   -1.148263D 02 -3.330448D 02 -7.537[illegible]4 01 -1.451701D 02 -4.248234D 01             *DATA
DATA*   -4.062226D 01 -1.846971D 01 -1.748[illegible] 01 -4.979704D 01 -2.841603D 03              *DATA
DATA*   -2.907538D 00 -4.540117D 00  3.433416D 00 -2.234046D 00                                *DATA
DATA* B( 25,1)                                                                                 *DATA
DATA*    1.334136D-01 -2.063771D-02  [illegible] 00 -5.295556D-01  2.971039D 00                 *DATA
DATA*   -7.207138D 00 -7.410684D-01 -9.[illegible] 00 -4.801629D 00 -1.323110D 01                *DATA
DATA*   -9.456[illegible]58D 00 -2.084658D 01 -1.[illegible] 01 -3.495630D 01 -2.827078D 01      *DATA
DATA*   -5.528976D 01 -4.055544 01 -9.087064D 01 -8.206377D 01 -1.527472D 02                    *DATA
DATA*   -2.339113D 02 -3.237697D 02 -1.053[illegible] 03 -1.100725D 03  3.032129D 03             *DATA
DATA*   -2.702639D-01 -1.117754D [illegible]  1.054987D 03 -2.257455D 02  3.558678D 02           *DATA
DATA*   -3.487713D 01  1.728068D 02 -4.856487D 01  9.511851D 01 -1.900782D 01                  *DATA
DATA*    4.364832D 01 -5.[illegible]2270 00  [illegible].006884 01 -4.840436D 00  3.476142D 01    *DATA
DATA*   -3.195[illegible] 00  6.[illegible]391 00 -1.040008D 00 -3.181673D 00                    *DATA
DATA* B( 26,1)                                                                                 *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

```
DATA*    2.636266D-01  9.314417D-03  6.845281D 00 -4.023892D-02  2.093264D 01        *DATA
DATA*   -1.649859D 00  2.710349D 01 -4.681960D 00  2.987310D 01 -1.277744D 01        *DATA
DATA*    3.920146D 01 -3.486335D 01  5.256712D 01 -8.617403D 01  7.211114D 01        *DATA
DATA*   -1.957605D 02  1.026344D 02 -4.440345D 02  1.586437D 02 -1.072072D 03        *DATA
DATA*    3.647118D 02 -3.465353D 03  1.088417D 03 -2.599125D 04 -2.702639D-01        *DATA
DATA*    9.608893D 04 -1.108627D 03 -2.556877D 04 -3.711204D 02 -3.902415D 03        *DATA
DATA*   -1.930816D 02 -1.063333D 03 -1.184028D 02 -3.655492D 02 -6.481241D 01        *DATA
DATA*   -1.102833D 02 -2.763398D 01 -4.038614D 01 -7.895538D 01 -6.477887D 01        *DATA
DATA*   -3.468534D 00 -1.029708D 01  2.707587D 00 -7.310893D-01                      *DATA
DATA* B( 27,1)                                                                      *DATA
DATA*    1.521997D-01 -1.790017D-02  2.825713D 00 -4.254301D-01  5.401261D 00        *DATA
DATA*   -5.756356D 00  3.015727D 00 -7.068315D 00 -3.582340D-01 -9.789538D 00        *DATA
DATA*   -3.747845D 00 -1.509634D 01 -8.821205D 00 -2.445637D 01 -1.598684D 01        *DATA
DATA*   -3.797637D 01 -2.644439D 01 -5.848425D 01 -4.370785D 01 -9.168046D 01        *DATA
DATA*   -1.048949D 02 -1.713795D 02 -2.370753D 02 -3.740235D 02 -1.117724D 03        *DATA
DATA*   -1.108627D 03  3.082335D 03 -2.863440D 00 -1.120868D 03  1.113888D 03        *DATA
DATA*   -2.359987D 02  3.428928D 02 -1.012241D 02  1.665602D 02 -3.972819D 01        *DATA
DATA*    7.158519D 01 -1.356409D 01  3.156056D 01 -1.796770D 01  5.377628D 01        *DATA
DATA*   -5.250594D 00  9.171072D 00 -3.678217D-01 -2.639177D 00                      *DATA
DATA* B( 28,1)                                                                      *DATA
DATA*    1.781989D-01  6.807965D-03  4.677167D 00  4.082446D-02  1.456005D 01        *DATA
DATA*    2.653941D-02  1.907830D 01 -1.140997D 00  2.087645D 01 -4.452110D 00        *DATA
DATA*    2.658673D 01 -1.371894D 01  3.515336D 01 -3.505014D 01  4.659466D 01        *DATA
DATA*   -7.911721D 01  6.373227D 01 -1.722157D 02  9.257520D 01 -3.797929D 02        *DATA
DATA*    1.914943D 02 -1.013487D 03  3.594274D 02 -3.819466D 03  1.094987D 03        *DATA
DATA*   -2.596877D 04 -2.863440D 00  9.006480D 04 -1.120284D 03 -2.630116D 04        *DATA
DATA*   -3.700050D 02 -3.561873D 03 -1.950082D 02 -9.887887D 02 -1.034443D 02        *DATA
DATA*   -2.704335D 02 -4.237832D 01 -9.410592D 01 -1.301752D 02 -1.472229D 02        *DATA
DATA*   -3.942923D 00 -2.140137D 01  2.179535D 00 -7.699601D-02                      *DATA
DATA* B( 29,1)                                                                      *DATA
DATA*    1.561559D-01 -1.433784D-02  3.117598D 00 -3.262686D-01  6.915097D 00        *DATA
DATA*   -4.324062D 00  5.691389D 00 -5.189663D 00  3.015777D 00 -6.996981D 00        *DATA
DATA*    6.889220D-01 -1.045643D 01 -2.527687D 00 -1.647293D 01 -6.972075D 00        *DATA
DATA*   -2.488219D 01 -1.307191D 01 -3.716243D 01 -2.217941D 01 -5.608375D 01        *DATA
DATA*   -5.119012D 01 -9.934921D 01 -9.539541D 01 -1.931482D 02 -2.257455D 02        *DATA
DATA*   -3.711204D 02 -1.120868D 03 -1.120284D 03  2.943884D 03 -8.041106D 01        *DATA
DATA*   -1.052526D 03  1.013568D 03 -2.241594D 02  3.092373D 02 -7.571747D 01        *DATA
DATA*    1.156725D 02 -2.582645D 01  4.775309D 01 -3.998456D 01  7.936239D 01        *DATA
DATA*   -7.507592D 00  1.160252D 01  2.031037D-01 -2.035819D 00                      *DATA
DATA* B( 30,1)                                                                      *DATA
DATA*    1.316495D-01  5.102408D-03  3.473059D 00  6.394908D-02  1.092380D 01        *DATA
DATA*    6.029756D-01  1.438459D 01  1.911674D-01  1.558486D 01 -1.138395D 00        *DATA
DATA*    1.931168D 01 -5.114671D 00  2.500715D 01 -1.441274D 01  3.237405D 01        *DATA
DATA*   -3.357927D 01  4.291861D 01 -7.281430D 01  5.974412D 01 -1.548263D 02        *DATA
DATA*    1.171087D 02 -3.811526D 02  1.901767D 02 -1.166891D 03  3.658678D 02        *DATA
DATA*   -3.902415D 03  1.113888D 03 -2.630116D 04 -8.041106D 01  9.367535D 04        *DATA
DATA*   -1.086327D 03 -2.395730D 04 -3.771579D 02 -3.308558D 03 -1.755628D 02        *DATA
DATA*   -7.316391D 02 -6.61[illegible]88D 01 -2.313813D 02 -2.231354D 02 -3.459155D 02        *DATA
DATA*   -3.942016D 00 -4.448002D 01  1.815795D 00  1.752070D-01                      *DATA
DATA* B( 31,1)                                                                      *DATA
DATA*    1.647446D-01 -1.224969D-02  3.440054D 00 -2.666201D-01  6.251341D 00        *DATA
DATA*   -3.497666D 00  7.793258D 00 -4.115440D 00  5.488360D 00 -5.408231D 00        *DATA
DATA*    3.743795D 00 -7.825298D 00  1.546464D 00 -1.196456D 01 -1.534807D 00        *DATA
DATA*   -1.755194D 01 -5.552865D 00 -2.542881D 01 -1.118664D 01 -3.711145D 01        *DATA
DATA*   -2.714782D 01 -6.319323D 01 -4.834740D 01 -1.148263D 02 -9.487713D 01        *DATA
DATA*   -1.930816D 02 -2.359987D 02 -3.700050D 02 -1.052526D 03 -1.086327D 03        *DATA
DATA*    2.796378D 03 -4.030888D 01 -1.015385D 03  9.791223D 02 -1.784676D 02        *DATA
DATA*    2.355306D 02 -5.362787D 01  8.564454D 01 -8.766814D 01  1.336610D 02        *DATA
DATA*   -1.112858D 01  1.538810D 01  6.338028D-01 -1.677835D 00                      *DATA
DATA* B( 32,1)                                                                      *DATA
DATA*    9.235937D-02  3.381721D-03  2.433921D 00  5.720934D-02  7.677648D 00        *DATA
DATA*    6.562708D-01  1.009599D 01  5.776707D-01  1.680022D 01  1.783416D-01        *DATA
DATA*    1.303454D 01 -1.236617D 00  1.651982D 01 -4.732520D 00  2.089544D 01        *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Cont'd)

```
DATA*  -1.218985D 01  2.692640D 01 -2.744627D 01  3.615512D 01 -5.846312D 01      *DATA
DATA*   6.837210D 01 -1.398131D 02  1.025499D 02 -3.930498D 02  1.726082D 02      *DATA
DATA*  -1.063333D 03  3.428928D 02 -3.561872D 03  1.013568D 03 -2.395730D 04      *DATA
DATA*  -4.030688D 01  8.413225D 04 -1.026772D 03 -2.123216D 04 -3.114163D 02      *DATA
DATA*  -2.346884D 03 -9.585397D 01 -6.034357D 02 -3.698353D 02 -8.203735D 02      *DATA
DATA*  -2.053900D 00 -6.741839D 01  1.379058D 00  2.258917D-01                    *DATA
DATA* B( 33,1)                                                                   *DATA
DATA*   1.727967D-01 -1.065699D-02  3.721413D 00 -2.242375D-01  9.361167D 00      *DATA
DATA*  -2.918342D 00  9.486618D 00 -3.381131D 00  7.437625D 00 -4.351600D 00      *DATA
DATA*   6.112893D 00 -6.126186D 00  4.616787D 00 -9.128874D 00  2.459304D 00      *DATA
DATA*  -1.305244D 01 -3.773550D-01 -1.843150D 01 -4.139045D 00 -2.619315D 01      *DATA
DATA*  -1.313912D 01 -4.334238D 01 -2.556482D 01 -7.537954D 01 -4.856467D 01      *DATA
DATA*  -1.184028D 02 -1.012241D 02 -1.990082D 02 -2.141594D 02 -3.771579D 02      *DATA
DATA*  -1.019385D 03 -1.026773D 03  2.644949D 03 -1.594092D 01 -8.744912D 02      *DATA
DATA*   8.300399D 02 -1.411753D 02  1.919613D 02 -2.202924D 02  2.581631D 02      *DATA
DATA*  -1.678221D 01  1.861673D 01  9.758627D-01 -1.418977D 00                    *DATA
DATA* B( 34,1)                                                                   *DATA
DATA*   7.016991D-02  2.776223D-03  1.828033D 00  4.516665D-02  5.779018D 00      *DATA
DATA*   5.569422D-01  7.553259D 00  5.878848D-01  7.969022D 00  5.252244D-01      *DATA
DATA*   9.391157D 00  5.351947D-02  1.165296D 01 -1.147643D 00  1.440646D 01      *DATA
DATA*  -4.050558D 00  1.806822D 01 -1.017671D 01  3.352191D 01 -2.261154D 01      *DATA
DATA*   4.303221D 01 -2.433598D 01  6.081776D 01 -1.481701D 02  9.511851D 01      *DATA
DATA*  -3.655492D 02  1.665602D 02 -9.887887D 02  3.092373D 02 -3.308558D 03      *DATA
DATA*   9.791223D 02 -2.123716D 04 -1.554037D 01  7.440568D 04 -9.117806D 02      *DATA
DATA*  -1.641822D 04 -1.481927D 02 -2.169873D 03 -6.825921D 02 -2.334350D 03      *DATA
DATA*   3.282218D 00 -1.844299D 02  1.085381D 00  2.029280D-01                    *DATA
DATA* B( 35,1)                                                                   *DATA
DATA*   1.364627D-01 -7.068556D-03  3.007434D 00 -1.452012D-01  7.815069D 00      *DATA
DATA*  -1.879377D 00  8.273675D 00 -2.153588D 00  6.878246D 00 -2.732921D 00      *DATA
DATA*   6.141236D 00 -3.778968D 00  5.432213D 00 -5.538182D 00  4.309382D 00      *DATA
DATA*  -7.804044D 00  2.809646D 00 -1.086876D 01  8.863107D-01 -1.524413D 01      *DATA
DATA*  -2.493776D 00 -2.489416D 01 -8.723447D 00 -4.248234D 01 -1.900782D 01      *DATA
DATA*  -6.481241D 01 -3.972819D 01 -1.034443D 02 -7.571747D 01 -1.755628D 02      *DATA
DATA*  -1.784676D 02 -3.114163D 02 -8.744912D 02 -9.117806D 02  2.557816D 03      *DATA
DATA*   3.982017D 01 -7.653476D 02  5.580946D 02 -6.202708D 02  4.726338D 02      *DATA
DATA*  -2.070861D 01  8.447927D 00  9.508213D-01 -9.248070D-01                    *DATA
DATA* B( 36,1)                                                                   *DATA
DATA*   4.219668D-02  1.189263D-03  1.057409D 00  2.582940D-02  3.431070D 00      *DATA
DATA*   3.287928D-01  4.452767D 00  3.719057D-01  4.643702D 00  4.056866D-01      *DATA
DATA*   5.374881D 00  3.434135D-01  6.555168D 00  4.132598D-02  7.952596D 00      *DATA
DATA*  -8.277458D-01  9.749608D 00 -2.752381D 00  1.235352D 01 -6.853996D 00      *DATA
DATA*   2.198426D 01 -1.705806D 01  2.960567D 01 -4.663260D 01  4.384892D 01      *DATA
DATA*  -1.102833D 02  7.158519D 01 -2.704335D 02  1.156725D 02 -7.316391D 02      *DATA
DATA*   2.355306D 02 -2.346884D 03  8.300599D 02 -1.641822D 04  3.982017D 01      *DATA
DATA*   6.259021D 04 -3.104736D 02 -1.630108D 04 -1.147634D 03 -7.307863D 03      *DATA
DATA*   1.373901D 01 -3.292719D 02  6.574142D-01  1.224666D-01                    *DATA
DATA* B( 37,1)                                                                   *DATA
DATA*   6.991731D-02 -3.285417D-03  1.557833D 00 -6.671609D-02  4.107930D 00      *DATA
DATA*  -8.613484D-01  4.431753D 00 -9.817588D-01  3.772110D 00 -1.238139D 00      *DATA
DATA*   3.473020D 00 -1.699596D 00  3.226312D 00 -2.475724D 00  2.792606D 00      *DATA
DATA*  -3.471139D 00  2.197677D 00 -4.813490D 00  1.447987D 00 -6.723361D 00      *DATA
DATA*   5.462631D-01 -1.092531D 01 -1.978584D 00 -1.846971D 01 -5.929227D 00      *DATA
DATA*  -2.763398D 01 -1.564053D 01 -4.237332D 01 -2.582645D 01 -6.617788D 01      *DATA
DATA*  -5.362787D 01 -9.325337D 01 -1.411753D 02 -1.481927D 02 -7.653476D 02      *DATA
DATA*  -3.104736D 02  3.149275D 03  8.702317D 02 -2.153826D 03  1.621586D 03      *DATA
DATA*  -1.615597D 01  3.344634D-01  5.320857D-01 -4.270772D-01                    *DATA
DATA* B( 38,1)                                                                   *DATA
DATA*   2.186068D-02  5.744046D-04  5.655908D-01  1.262911D-02  1.766168D 00      *DATA
DATA*   1.648454D-01  2.284403D 00  1.900754D-01  2.371188D 00  2.159674D-01      *DATA
DATA*   2.759063D 00  2.130484D-01  3.302152D 00  1.227264D-01  3.973685D 00      *DATA
DATA*  -1.322243D-01  4.723869D 00 -9.388302D-01  6.038317D 00 -2.499811D 00      *DATA
DATA*   1.[illegible]D 01 -6.[illegible]D 00  1.354226D 01 -1.748354D 01  2.306684D 01      *DATA
DATA*  -4.[illegible]D 01  3.150583D 01 -9.410592D 01  4.779309D 01 -2.313813D 02      *DATA
```

TABLE IX. NORMALIZED MODAL DAMPING MATRIX-LATERAL MODEL (Concl'd)

```
DATA*   9.564494D 01 -6.034357D 02  1.919613D 02 -2.169873D 03  5.580946D 02        *DATA
DATA*  -1.630108D 04  8.702317D 02  5.870195D 04 -1.876947D 03 -2.746105D 04        *DATA
DATA*   1.883305D 01 -3.948304D 02  3.395642D-01  6.151902D-02                      *DATA
DATA* B( 39,1)                                                                      *DATA
DATA*   1.796411D-01 -7.621839D-03  4.043411D 00 -1.538768D-01  1.080243D 01        *DATA
DATA*  -1.985704D 00  1.184680D 01 -2.259274D 00  1.029985D 01 -2.853629D 00        *DATA
DATA*   9.751822D 00 -3.943017D 00  9.441253D 00 -5.807634D 00  8.720188D 00        *DATA
DATA*  -8.272566D 00  7.691833D 00 -1.171548D 01  6.455841D 00 -1.679280D 01        *DATA
DATA*   6.479889D 00 -2.810585D 01  1.857276D 00 -4.979704D 01 -4.840436D 01        *DATA
DATA*  -7.899538D 01 -1.796770D 01 -1.301752D 02 -3.998456D 01 -2.231354D 02        *DATA
DATA*  -8.768814D 01 -3.698353D 02 -2.202904D 02 -6.825921D 02 -6.202708D 02        *DATA
DATA*  -1.147634D 03 -2.153826D 03 -1.876947D 03  3.101490D 03 -2.819538D 03        *DATA
DATA*  -4.568762D 01 -2.046246D 02  1.454178D 00 -9.945811D-01                      *DATA
DATA* B( 40,1)                                                                      *DATA
DATA*   3.955821D-02  1.013940D-03  1.024050D 00  2.277915D-02  3.188586D 00        *DATA
DATA*   2.932681D-01  4.119399D 00  3.396201D-01  4.269776D 00  3.912690D-01        *DATA
DATA*   4.899042D 00  3.946990D-01  5.922433D 00  2.577902D-01  7.109185D 00        *DATA
DATA*  -2.539483D-01  8.603053D 00 -1.482703D 00  1.072531D 01 -4.052946D 00        *DATA
DATA*   1.874432D 01 -1.040071D 01  2.442855D 01 -2.841603D 01  3.476142D 01        *DATA
DATA*  -6.477887D 01  5.377628D 01 -1.472229D 02  7.906239D 01 -3.459155D 02        *DATA
DATA*   1.336610D 02 -8.203735D 02  2.581631D 02 -2.334350D 03  4.726338D 02        *DATA
DATA*  -7.307863D 03  1.621586D 03 -2.746105D 04 -2.819538D 03  5.720335D 04        *DATA
DATA*   7.220720D 01 -1.536248D 03  6.128355D-01  1.092302D-01                      *DATA
DATA* B( 41,1)                                                                      *DATA
DATA*   1.655039D-02 -1.011291D-03  3.573408D-01 -2.036477D-02  9.041585D-01        *DATA
DATA*  -2.617402D-01  9.217223D-01 -2.967337D-01  7.231941D-01 -3.559080D-01        *DATA
DATA*   5.670916D-01 -4.836382D-01  4.384197D-01 -6.676841D-01  2.309020D-01        *DATA
DATA*  -8.750347D-01 -3.325492D-02 -1.116256D 00 -3.654479D-01 -1.411978D 00        *DATA
DATA*  -1.095255D 00 -2.052785D 00 -1.945772D 00 -2.909538D 00 -3.195901D 00        *DATA
DATA*  -3.468534D 00 -5.250594D 00 -3.942923D 00 -7.507592D 00 -3.942016D 00        *DATA
DATA*  -1.112898D 01 -2.053900D 00 -1.678221D 01  3.282218D 00 -2.020861D 01        *DATA
DATA*   1.373901D 01 -1.615597D 01  1.883305D 01 -4.568762D 01  7.220720D 01        *DATA
DATA*   1.250747D 02  1.139430D 02  1.031702D-01 -1.266720D-01                      *DATA
DATA* B( 42,1)                                                                      *DATA
DATA*   9.849510D-03  2.003591D-04  2.523326D-01  4.488966D-03  7.774953D-01        *DATA
DATA*   5.769283D-02  9.945024D-01  6.707765D-02  1.020673D 00  7.684544D-02        *DATA
DATA*   1.158402D 00  7.591911D-02  1.382734D 00  4.643162D-02  1.634158D 00        *DATA
DATA*  -5.513297D-02  1.938869D 00 -2.885304D-01  2.356776D 00 -7.569117D-01        *DATA
DATA*   3.992837D 00 -1.870229D 00  4.925233D 00 -4.840117D 00  6.530391D 00        *DATA
DATA*  -1.029708D 01  9.171072D 00 -2.140137D 01  1.160252D 01 -4.446002D 01        *DATA
DATA*   1.538810D 01 -8.741839D 01  1.861673D 01 -1.844299D 02  6.447927D 00        *DATA
DATA*  -3.292719D 02  3.344634D-01 -3.948304D 02 -2.046246D 02 -1.536248D 03        *DATA
DATA*   1.139430D 02  5.136421D 03  1.465141D-01  2.034810D-02                      *DATA
DATA* B( 43,1)                                                                      *DATA
DATA*   5.702142D-02 -5.793316D-02 -2.585315D 00 -3.546018D 00 -3.922787D 01        *DATA
DATA*  -7.055538D 01 -2.712641D 01 -1.265674D 01 -1.750387D 01 -2.578020D 00        *DATA
DATA*  -1.201681D 01  1.455488D 00 -8.553711D 00  3.183934D 00 -6.605378D 00        *DATA
DATA*   3.798254D 00 -4.811527D 00  3.806220D 00 -3.499789D 00  3.539978D 00        *DATA
DATA*  -3.459951D 00  3.716627D 00 -1.964485D 00  3.433410D 00 -1.040008D 00        *DATA
DATA*   2.707587D 00 -3.678217D-01  2.179535D 00  2.031037D-01  1.819795D 00        *DATA
DATA*   6.338028D-01  1.379088D 00  9.758527D-01  1.085381D 00  9.508213D-01        *DATA
DATA*   6.574142D-01  5.300897D-01  3.395642D-01  1.434178D 00  6.120355D-01        *DATA
DATA*   1.031702D-01  1.465141D-01  1.242545D 02 -1.178997D 02                      *DATA
DATA* B( 44,1)                                                                      *DATA
DATA*   3.906821D 00  1.282450D-01  8.789148D 01 -4.651851D 01  1.540950D 02        *DATA
DATA*  -1.428479D 03 -1.788496D 01 -3.098549D 02 -2.722004D 01 -1.351879D 02        *DATA
DATA*  -1.935637D 01 -6.724796D 01 -1.475960D 01 -3.863778D 01 -1.104063D 01        *DATA
DATA*  -2.258753D 01 -8.112236D 00 -1.290826D 01 -5.929870D 00 -7.211507D 00        *DATA
DATA*  -6.061544D 00 -4.675211D 00 -4.201503D 00 -2.234046D 00 -3.181373D 00        *DATA
DATA*  -7.310893D-01 -2.639177D 00 -7.699601D-02 -2.035819D 00  1.752070D-01        *DATA
DATA*  -1.677835D 00  2.258917D-01 -1.418977D 00  2.029280D-01 -9.248070D-01        *DATA
DATA*   1.224666D-01 -4.270772D-01  6.151902D-02 -9.945811D-01  1.092302D-01        *DATA
DATA*  -1.266720D-01  2.034810D-02 -1.178997D 02  5.092807D 03                      *DATA
```

3.4 STRUCTURAL RESPONSE ANALYSIS

This phase of the program involved generating the structural response acceleration environments of the two fuzes. This task consequently represents the principal effort conducted necessary to meet the basic study objectives. The two other phases discussed above were preparatory to this final effort in that they provide (1) the loading environment and (2) the dynamic model for subsequent structural response analysis.

Standard modal response analysis techniques were inappropriate for this problem. The reason for this is basically due to the characteristics of the loading environment. It was discontinuous, non-linear, and voluminous in terms of the amount of data necessary to describe the transient axial and transverse time history of loading (for the complete trajectory) for each coordinate of motion and for each impact condition.

The method of analysis utilized to determine the fuze response environments consisted of generating the coupled simultaneous differential equations of motion for each coordinate and solving them directly by numerical integration. The loading environment, which was generated by the 2-D Code, was applied in a digital format on magnetic tape with linear interpolation between data points. A digital loading history was included for each coordinate of lumped parameter system. The set of differential equations in matrix format was of the form:

$$M_N \ddot{X} + K_N X + C_N \dot{X} = F(x, t)$$

where

$N =$ 42 for the axial model

$N =$ 44 for the transverse model (17 translational and 17 rotational coordinates)

$M =$ Mass matrix

$K =$ Stiffness matrix

$C =$ Modal damping matrix

$M, K, C =$ Took on values associated with the axial and transverse models, respectively.

These sets of equations were mechanized for solution and solved by the contractor's Computer Code No. 2947, which incorporates the Adams predictor corrector numerical integration routine. This code and the integration routines are described in Appendix III.

Results

The results of this analysis include the axial and lateral, forward and aft fuze acceleration environments for the full spectrum of impact conditions

presented in Table I. For ease in data utilization and due to the characteristics of the environments, the results are presented in two time regimes, i.e., early during the impact event and later during penetration. The initial impact event excited significant structural response of the MK82 configuration. This early time response resulted in the peak acceleration environments experienced by the fuzes. These accelerations were characterized by high frequency oscillation which rapidly damped out during the subsequent penetration of the projectile. As these oscillations damped out, the rigid body accelerations increased until they reached a peak later in the trajectory. This second peak was, however, in most cases less than the initial high frequency response. In view of the fact that structural response was only present during the initial phase of the impact event, therefore, structural response data is provided only for that initial phase, and subsequent late time environments can be obtained from the rigid body response directly. The above described characteristics are demonstrated by reference to the following example response history. The condition chosen is for the maximum impact velocity at an obliquity of 70 degrees. Figures 15 and 16 present the rigid body response in the axial and lateral directions, respectively, for both fuzes (GZ1, GX1 = forward fuze, GZ3, GX3 = aft fuze).

The peak axial loads for the forward and aft fuze are 1200 and 450 g's, respectively and the peak lateral loads are 1700 and 1800 g's, respectively. These peaks occur at approximately 10 to 15 milliseconds after initial impact.

Figures 20 through 23 are plots of the axial accelerations for the forward fuze, while Figures 24 through 27 are for the aft fuze taking into consideration the flexibility of the warhead structure. Note in Figure 20 the peak early time axial acceleration environment for the forward fuze is 1100 g's and occurs at $t \simeq 0.2$ ms. Figures 28 through 30 represent continuations in time for the forward fuze well axial accelerations. The second peak of 830 g's is reached at time $\simeq 12$ ms. This corresponds to the rigid body peak noted in Figure 15 without centrifugal acceleration coupling. According to Figure 15, this contribution is 400 g's, bringing the total to 1230 g's.

Figure 24 presents the early time axial structural response data for the aft fuze. The peak value is 1200 g's, and the time of occurrence is $t \simeq 0.5$ ms. The late time peak occurs at $t \simeq 11$ ms and corresponds to the rigid body environment of 830 g's. Again this value is to be corrected by the centrifugal field effects, resulting in an actual acceleration of 430 g's.

Similar data comparisons were made for the lateral case and for different impact conditions. In all cases, the only pertinent structural response occurred during the first few milliseconds of the event and the late time response was essentially due to rigid body effects.

The basic results of the structural response analysis are presented in Appendix IV. Table X delineates the contents of Appendix IV. These results represent direct computer outputs in graphical form, and the data represents the fuze well acceleration environments for the first 1.5 ms of the impact event.

Again for ease in data utilization and interpretation, this information is summarized in Figures 2 through 4. These results are self-explanatory.

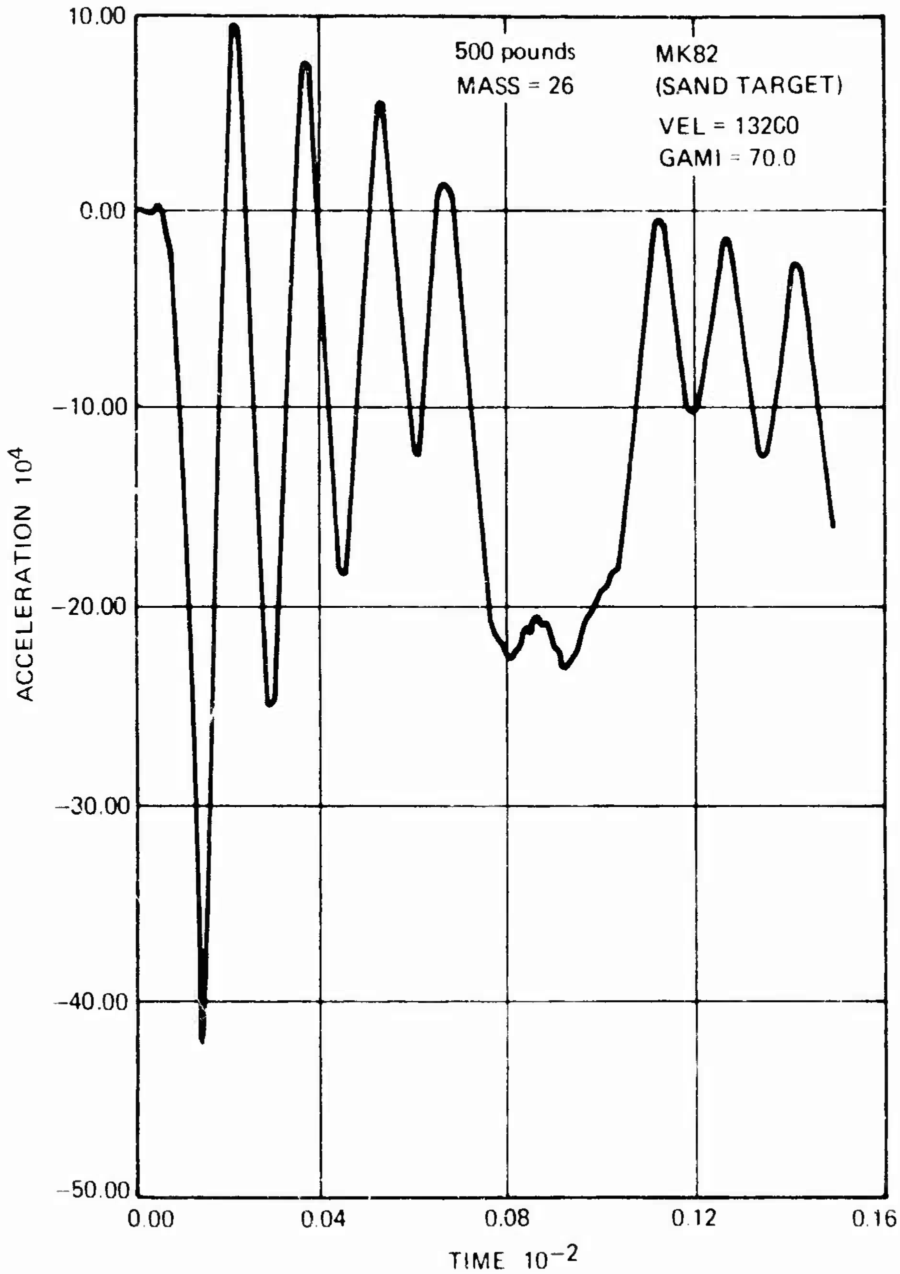

Figure 20 AXIAL RESPONSE FORWARD FUZE $0 < T < 0.15$ ms

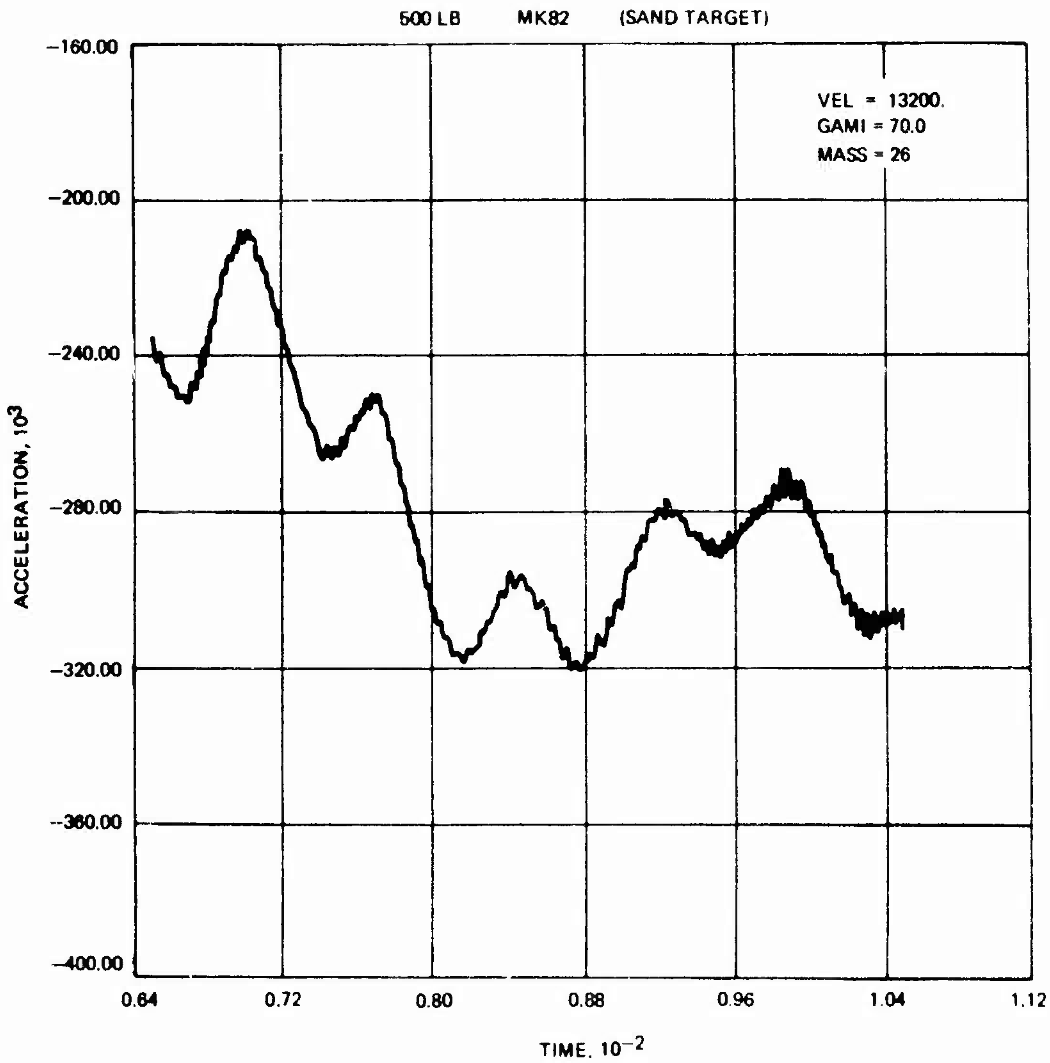

Figure 21 AXIAL RESPONSE FORWARD FUZE 6.4 < T < 10.4 ms

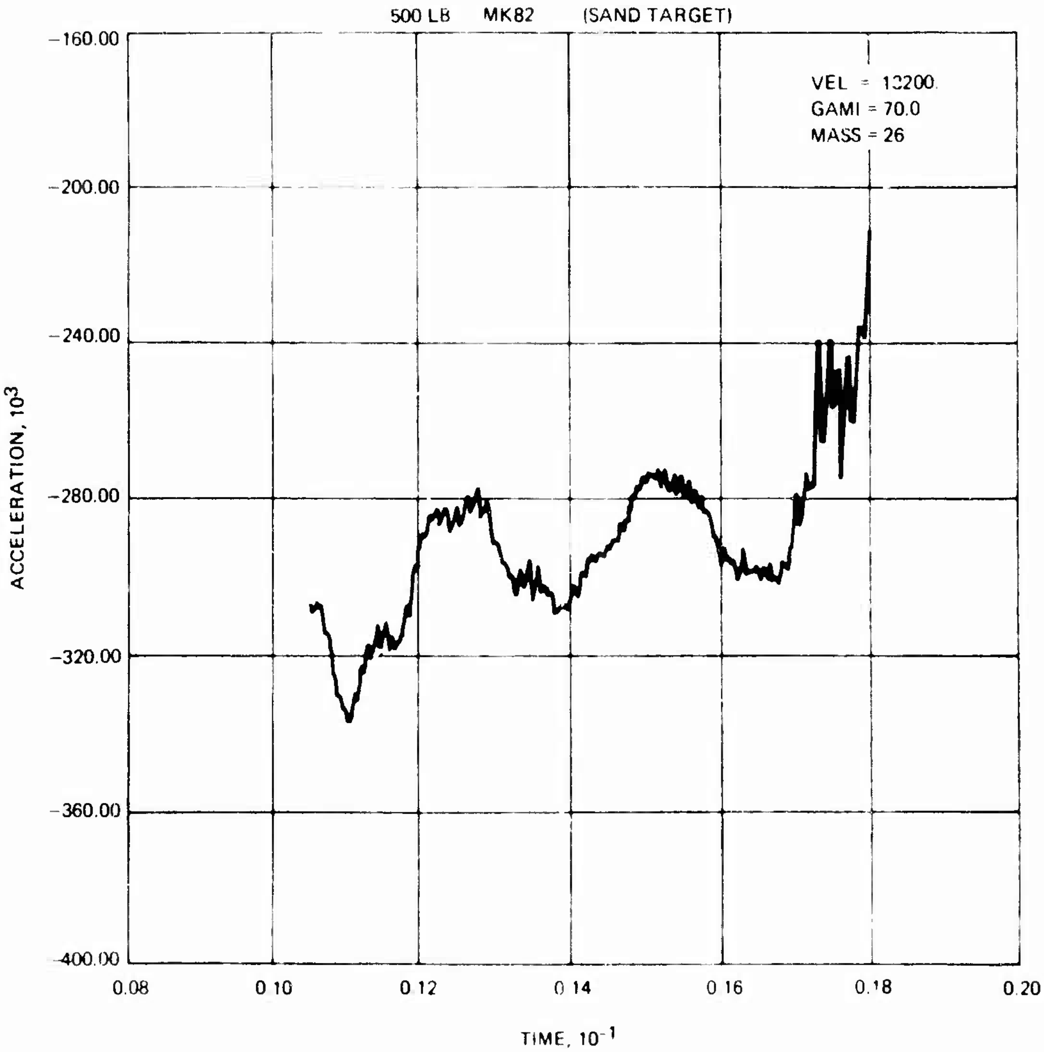

Figure 22 AXIAL RESPONSE FORWARD FUZE 10 < T < 18 ms

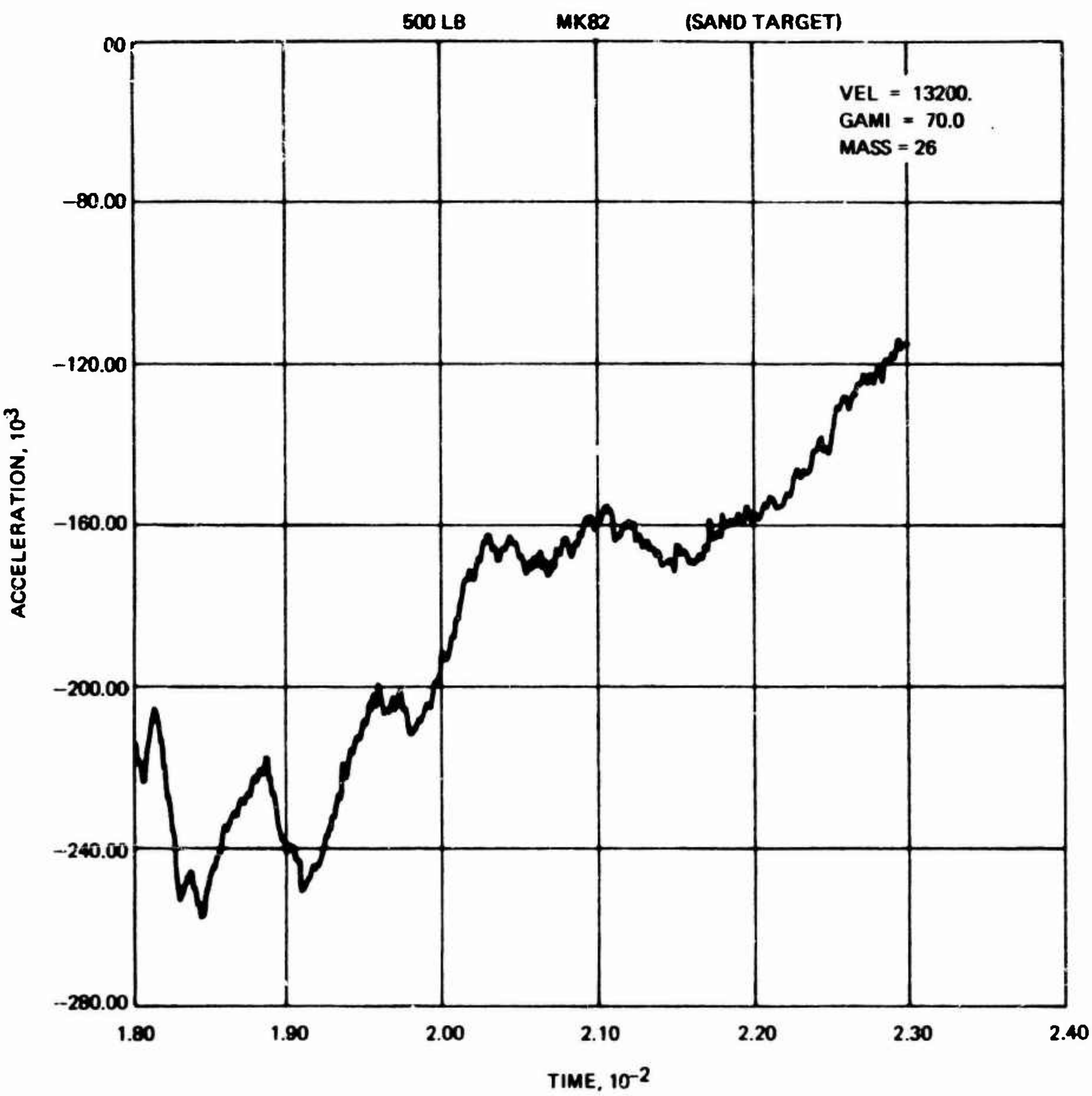

Figure 23 AXIAL RESPONSE FORWARD FUZE 18 < T < 23 ms

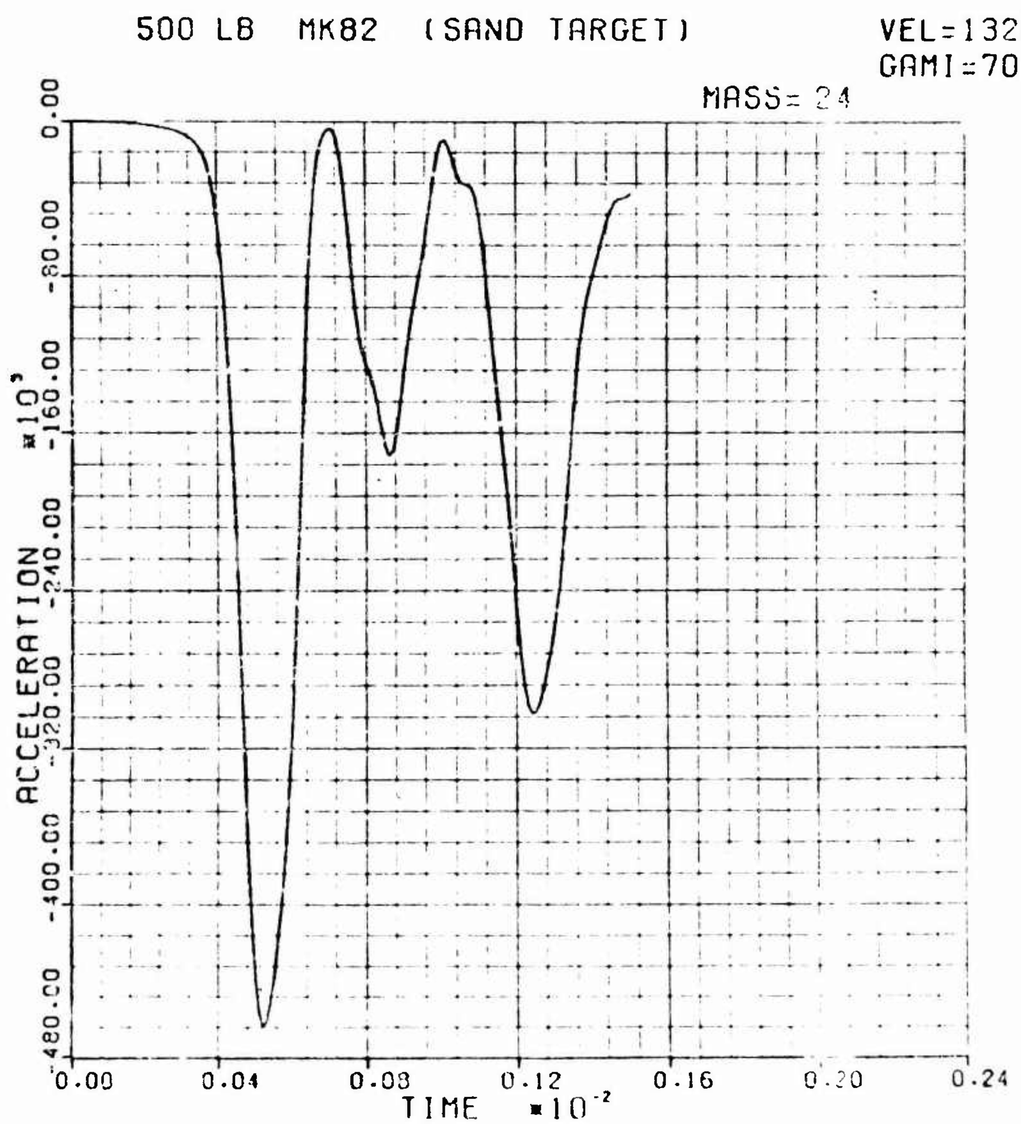

Figure 24 AXIAL RESPONSE AFT FUZE 0 < T < 1.5 ms

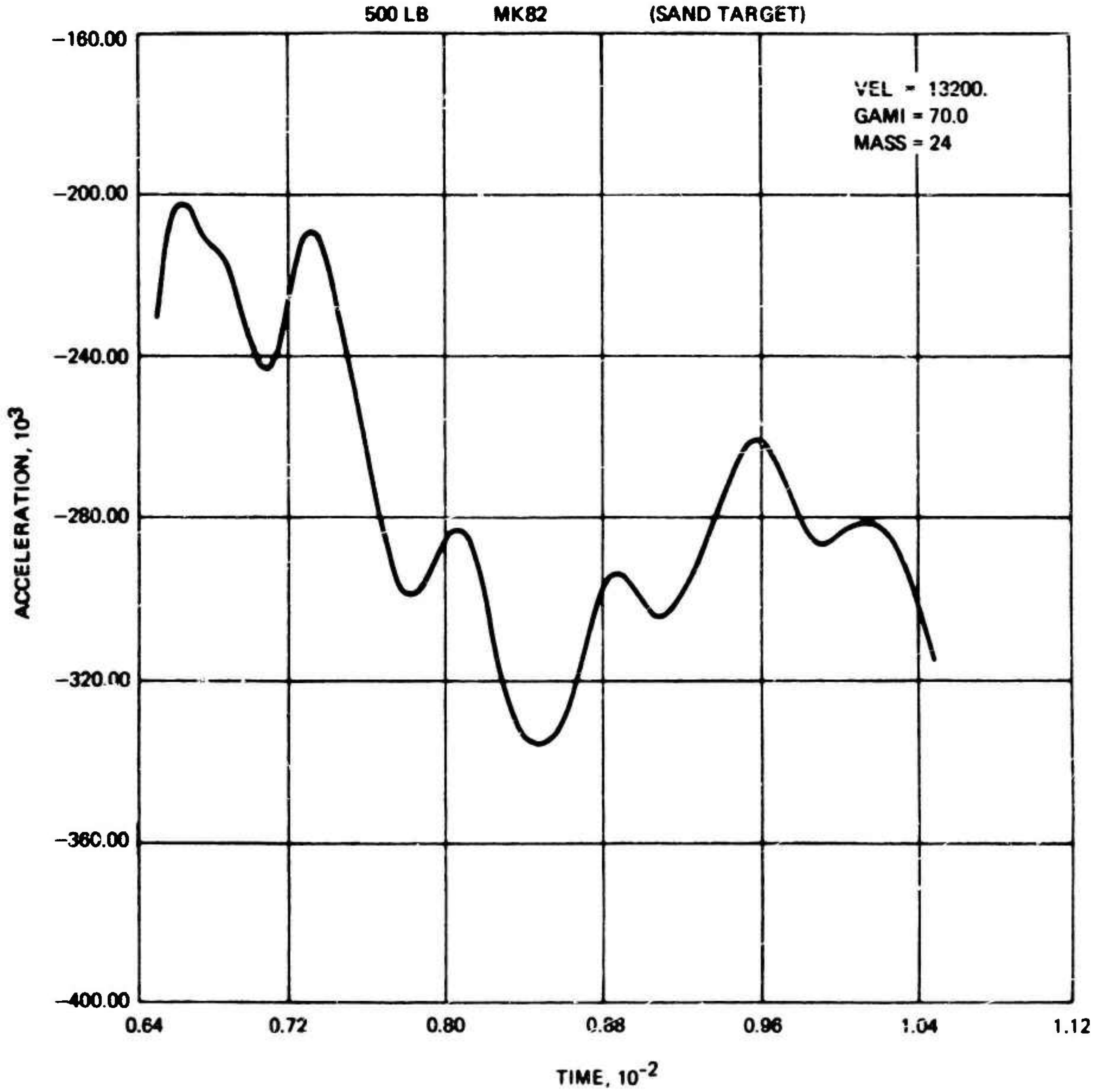

Figure 25 AXIAL RESPONSE AFT FUZE 6.4 < T < 10.4 ms

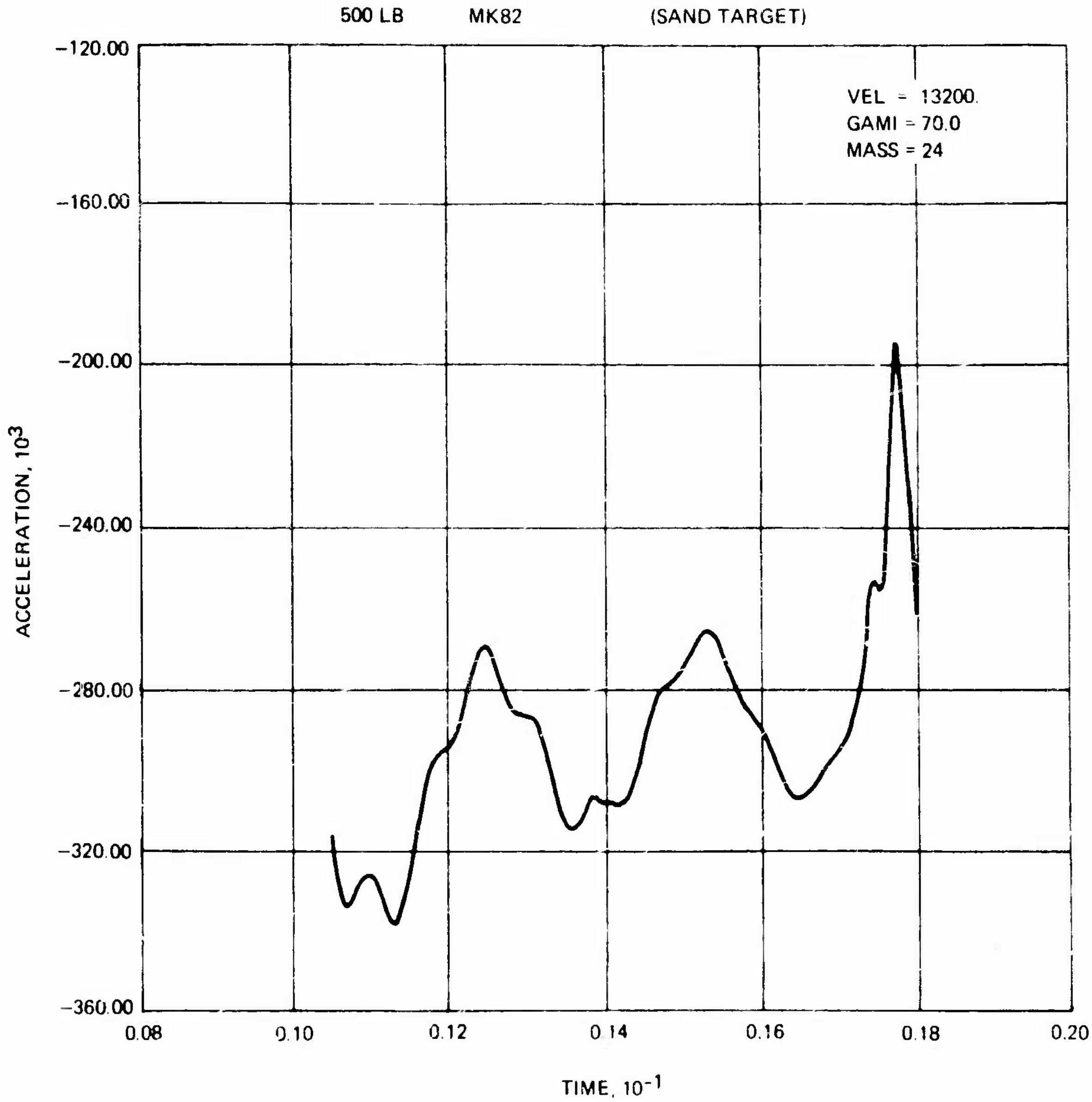

Figure 26 AXIAL RESPONSE AFT FUZE $10 < T < 18$ ms

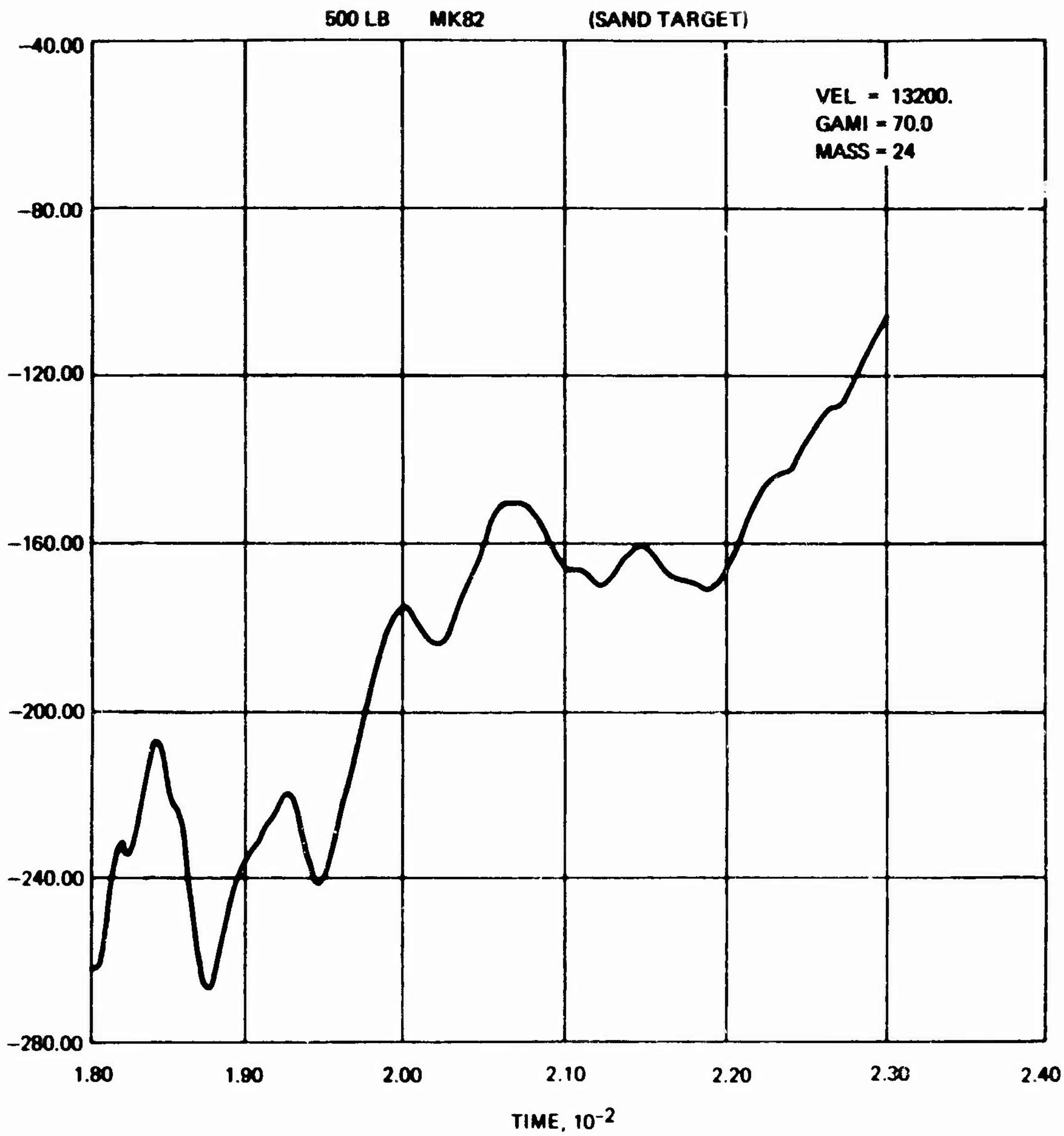

Figure 27 AXIAL RESPONSE AFT FUZE 18 < T < 23 ms

TABLE X. FUZE ENVIRONMENT SUMMARY- MK82 WARHEAD

(Axial Response) Sand Impacts

Time Regime 0.0 - 1.5 Milliseconds

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
30			
35			
40			
45			
55			
60			
65			
70	13,200	24 - Aft Fuze	
20	10,800	26 - Forward Fuze	
25			
35			
40			
45			
55			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
35			
40			
45			
55			
65			
70	10,800	24 - Aft Fuze	Acceleration

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
30			
35			
45			
55			
65			
70	7,200	24 - Aft Fuze	Acceleration
		(Lateral Response)	
20	13,200	5 - Forward End of	Acceleration
35		Forward Fuze	
45			
55			
65		5 - Forward End of	
70		Forward Fuze	
20		43 - Aft End of	
35		Forward Fuze	
45			
55			
65		43 - Aft End of	
70		Forward Fuze	
20		41 - Forward End of	
35		Aft Fuze	
45			
55			
65		41 - Forward End of	
70	13,200	Aft Fuze	Acceleration

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Cont'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	39 - Aft End of Aft Fuze	Acceleration
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70	13,200		
20	10,800	5 - Forward End of Forward Fuze	
25			
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70			
20		43 - Aft End of Forward Fuze	
25			
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
25			
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70			
20		39 - Aft End of Aft Fuze	
25			
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70	10,800		
20	7,200	5 - Forward End of Forward Fuze	
25			
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70	7,200		Acceleration

TABLE X. FUZE ENVIRONMENT SUMMARY-MK82 WARHEAD (Concl'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	43 - Aft End of	Acceleration
25		Forward Fuze	
35			
45			
55			
65		43 - Aft End of	
70		Forward Fuze	
20		41 - Forward End of	
25		Aft Fuze	
35			
45			
55			
65		41 - Forward End of	
70		Aft Fuze	
20		39 - Aft End of	
25		Aft Fuze	
35			
45			
55			
65		39 - Aft End of	
70	7,200	Aft Fuze	Acceleration

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SECTION III

CONCLUSIONS AND RECOMMENDATIONS

The objectives of this program were to establish the fuze environments due to MK82 impacts into sand. These objectives were accomplished, and the information contained herein represents the specification of MK82 fuze impact environments data related to sand impacts.

Some care should be used in using and interpreting this data for fuze system functioning investigations. There are two destinct regimes of peak accelerations: early time and late time. The early time is characterized by high frequency oscillations and, in some cases, acceleration direction reversals (of the same order) are experienced. The late time peaks are associated with rigid body response and are characteristically low frequency, i.e., on the order of total penetration duration. The point to be made is that fuze functioning reactions may be sensitive to the two types of acceleration environments, and this should be taken into consideration during fuze functioning investigations.

One of the significant results of this study program was the fact that the effects of projectile flexibilities were significant for sand impact situations. For most impact cases investigated, early time structural response accelerations were significantly higher than peak rigid body acceleration levels. The implication of this result is that for impacts into other target media, which generally will be more resistant to penetration than sand, much higher magnification of acceleration environments due to structural response effects will occur. Magnification factors of five or greater are expected, and this will undoubtedly have a significant effect upon certain fuze systems.

Another interesting and, in some cases, significant result of the study was related to the fuze system mount design. During the modeling analysis, particular attention was given to the mechanical interface design details between the fuze and the main shell structure.

During subsequent structural response analysis, it was determined that, due to the characteristics of these designs, the loading environments transmitted to the fuzes were, in some instances, attenuated and in others they were magnified.

For example, with reference to Table XI below, loading magnification occurred for the aft fuze in both the axial and lateral directions, where attenuation occurred for the forward fuze in both directions. Also, in both cases, magnification was on the order of 30 percent while attenuation was approximately down by 20 percent.

Fuze mount designs which capitalize on this kind of behavior should be considered. It may be possible to develop fuze mount designs which are more sensitive to graze-type impact conditions while desensitizing axial environments. The result would be a more efficient compatible system for broader impact environment utilization.

TABLE XI. FUZE MOUNT DESIGN EFFECTS

V = 1100 = 70^{o} Fuze	Loading Direction	Fuze Peak Acceleration	Nearest Main Structure Acceleration	Ratio
		g's	g's	
Fwd.	Axial	1100	1550	0.71
	Lateral	4000	4900	0.82
Aft	Axial	1200	930	1.3
	Lateral	2600	1940	1.34

Prior to the development of the technology utilized in this program (i.e., the capability to determine well-defined impact loading environments), only crude estimates could be made concerning the accelerations experienced by fuze systems. In the past, it was pointless to perform detailed structural response analysis because of the uncertainties associated with the applied loading environments.

In view of the above, and because of the several significant findings determined during the conduct of this program, the following additional study areas are suggested:

1. Fuze Environments for Other Target Media

Sand is one of the so-called soft targets. There are, however, other targets which may be softer (i.e., wherein lower acceleration environments are experienced by the fuze systems). These include snow, jungle canopy, and terrain representative of marshy areas. There are also much harder targets such as steel armor, concrete, frozen earth, clay, etc. Some of these targets are of more interest than others for reasons of present applications and present performance results. System upgrading, however, may make it essential to know the impact environment into these additional media.

Programs structured to determine fuze environments for additional media would be of two types. These include:

a. Efforts similar to the present program conducted for sand, i.e., strictly analytical.

b. Programs which consist of both testing and analysis. Some of the above mentioned media have not been categorized relative to their ballistic resistance to penetration, and this would be required prior to the parametric study for establishing fuze environments.

2. MK82 Structural Integrity Evaluation

For proximity, air burst, or point contact (superquick) modes of operation, impact structural integrity of the MK82 bomb is of no particular interest. The munition is initiated prior to catastrophic structural failure. For delay mode or zero g sensing missions, structural integrity must be maintained in order to insure proper functioning. Structural failure or excessive structural response accelerations or deformation can be directly responsible for duds, low order functioning, or improper initiation timing.

The purpose of a study structured to evaluate the structural integrity of the MK82 warhead would be to establish the bounds of impact conditions and impact media for which structural integrity was maintained. This information could be used directly to determine:

a. MK82 bomb operating regimes (intact impact), impact conditions, and target spectrum.

b. Delay mode fuze settings to result in optimum yields.

c. Design specification for delay mode fuze systems.

d. Structural design upgrading specification (if required).

3. Impact Environments Analysis for Other Warheads

The present program and the above recommended study areas were geared to the MK82 warhead. These same studies which include fuze environments specification and structural integrity evaluation can be conducted for other warhead configurations, such as MK84, M117, M118, HSM, Bullpup, 2.75-inch rocket, and other similar types.

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APPENDIX I

155MM FUZE ENVIRONMENTS PROGRAM SUMMARY

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The 155mm Fuze Environments Program, Contract No. DAAA21-71-C-0517, was conducted by the contractor for Picatinny Arsenal to establish the forces acting on the 155mm projectile for impacts into sand and soil targets to develop a Three-Dimensional Impact and Penetration Computer Code for simulation of the terminal impact event. This activity was successfully completed in September 1972.

The two principal objectives of the Phase I activity were:

1. Develop a resistance-to-penetration-force law for projectile impacts into sand and soil targets.

2. Develop a Three-Dimensional Impact and Penetration Computer Program.

The first objective was satisfied by an analytical and experimental program which resulted in verified force laws for projectile impacts into sand and soil targets. This activity was conducted over the first five months of the program. The second effort, which resulted in the successful development of the computer code, was conducted over a seven-month period.

The technical approach utilized to develop the sand and soil penetration force laws consisted of the conduct of two test programs. In the first one, both spinning and non-spinning 20mm projectiles were impacted into sand and soil targets. In the second test program, full-caliber 155mm projectiles were impacted into sand targets. In both test programs, the targets were instrumented with velocity grids and yaw cards positioned along the trajectory of the projectile, both in and out of the target. These were used to monitor the projectile position and orientation time histories during the penetration event. In addition, flash x-ray was also utilized to monitor the impact event for the 20mm tests. These tests were conducted for a variety of impact angles and obliquities to ensure that the final force law was applicable across the entire range of impact variables.

Typical analytical prediction versus test trajectories are shown in Figures I-1 through I-6. The dotted lines represent the test data while the solid line and the projectile drawings are generated by the 2-D Code graphical output routines. It is evident from the figures that excellent agreement is obtained between theory and test.

The results of the non-spinning 20mm tests were then analyzed and simulated using the contractor's Two-Dimensional Impact and Penetration Computer Code. This code, which simulates the impact and penetration of a non-spinning projectile into a target medium, utilizes a general resistance to penetration force. The analysis was conducted by parametrically varying the force law coefficients and target surface effects, such as chipping and cratering, until all the test results were successfully simulated. Since the test simulations

were conducted for various velocities and obliquities, this demonstrated the satisfactory performance of the sand and soil force laws over the impact velocity and angle range of interest.

Once the development of the force law was successfully completed, the development of the Three-Dimensional (6-degree-of-freedom) Impact and Penetration Computer Code was begun. The development of this computer code resulted in an analytical tool with the capability to simulate the three-dimensional motion and forces acting upon a spinning projectile impacting into sand and soil. Upon completion of the 3-D Code, it was used to simulate the spinning 20mm tests and the full-scale 155mm sand impact tests. The results of this analysis indicated that the code was functioning properly, and it could be used to simulate and analyze 6-degree-of-freedom sand impact and penetration events.

This program was successful in accomplishing all of the study and testing objectives. The most noteworthy accomplishments include:

(1) Successful test program - The testing and instrumentation procedures were more than adequate to provide the required trajectory/time history data.

(2) 3-D Code development - The computer program was generated, is operational, and simulates three-dimensional motion of a projectile impacting, penetrating, and/or ricocheting into sand or soil targets.

(3) Determination of projectile impact loading environments and resulting trajectories through analytical simulation - Both the 20mm non-spinning and the spinning 20mm and 155mm impact test conditions have been analytically simulated with the 2- and 3-D Codes, respectively. The results of these simulations are the applied resistance to penetration loading environments which the projectile experiences during the penetration event.

The overall results of the program involve a significant advancement in the state-of-the-art of impact environment technology. This program has resulted in the demonstrated ability to determine impact environments through analytical simulation.

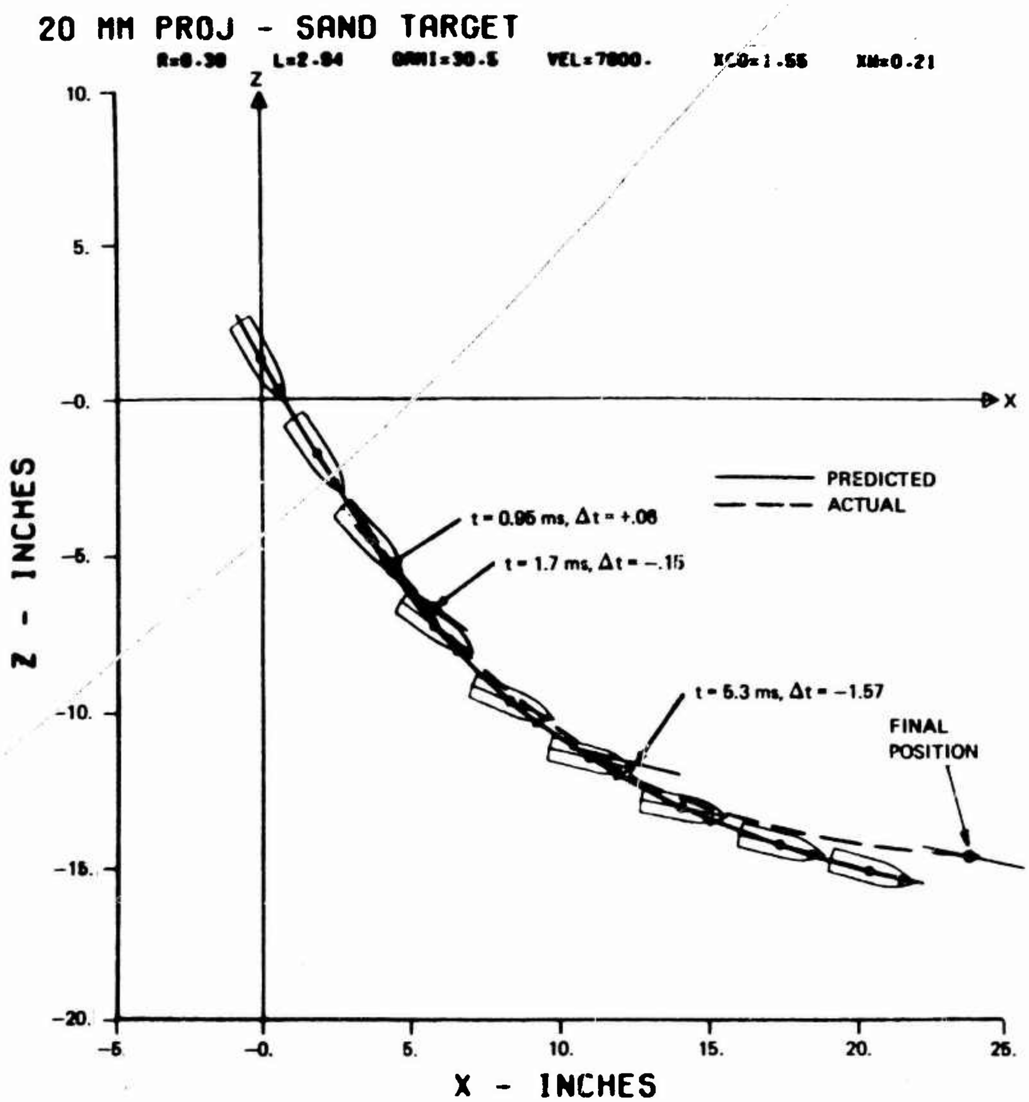

Figure I–1 SIMULATION RESULTS – TEST 8

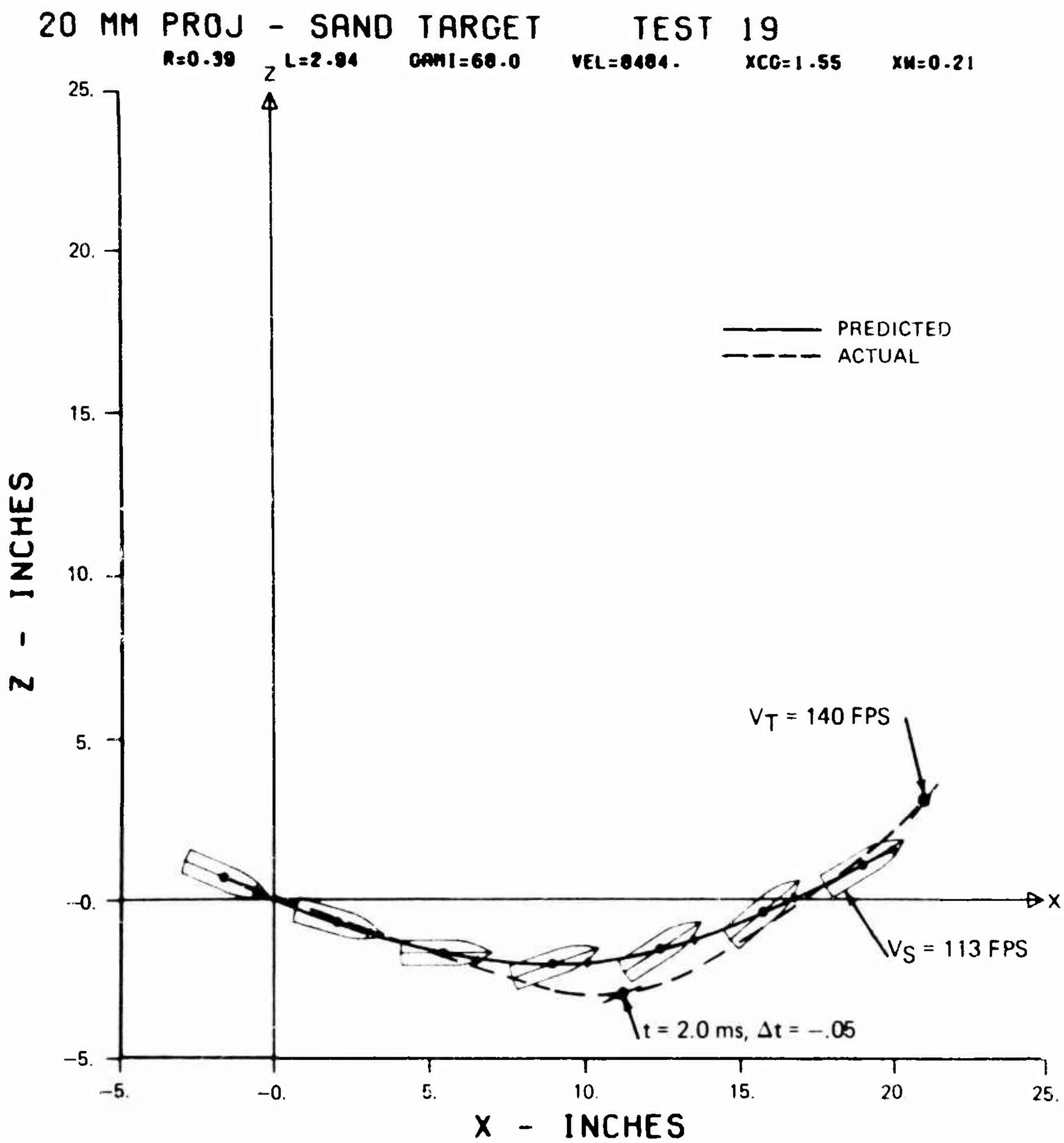

Figure I–2 SIMULATION RESULTS – TEST 19

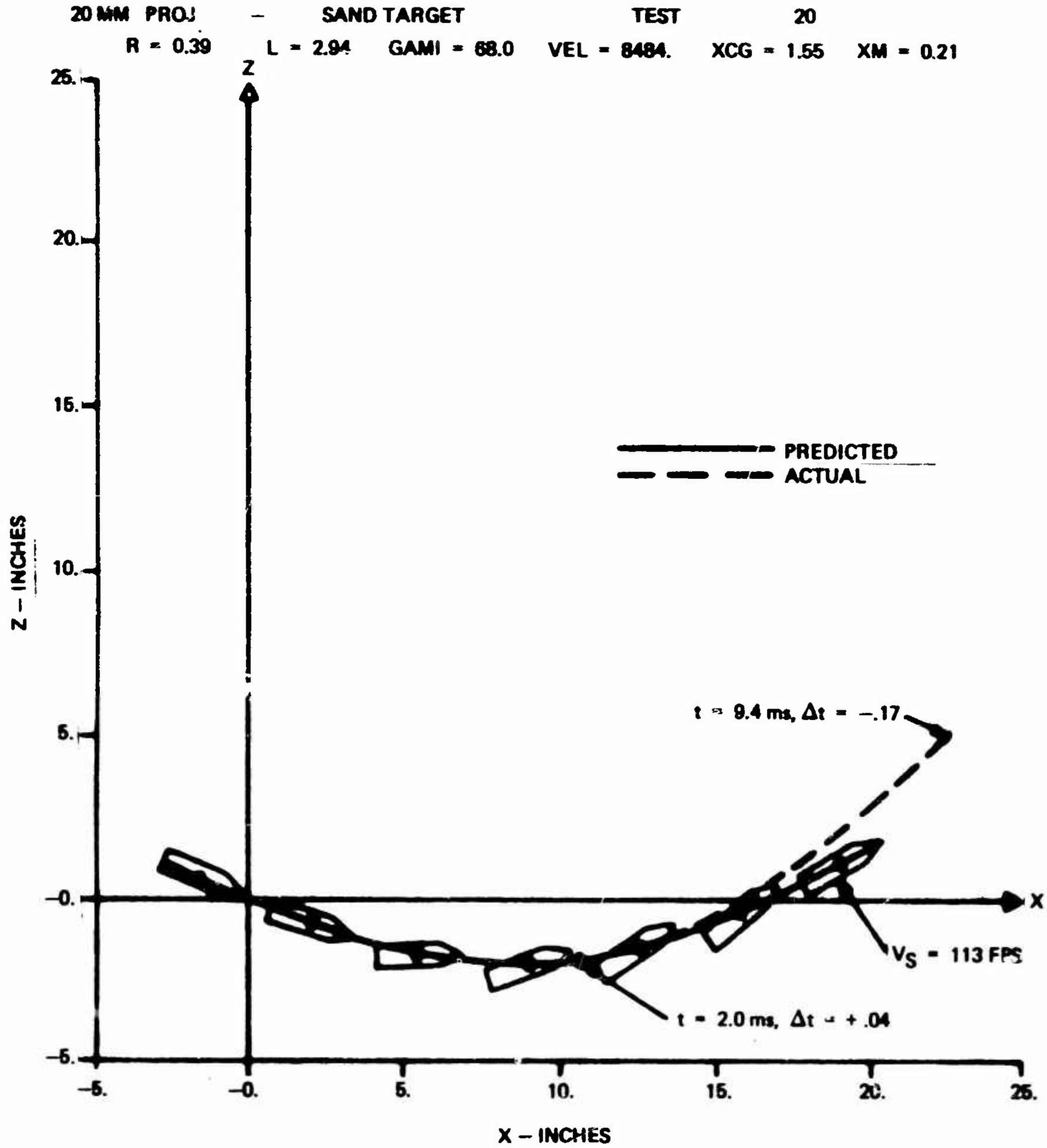

Figure I-3 SIMULATION RESULTS - TEST 20

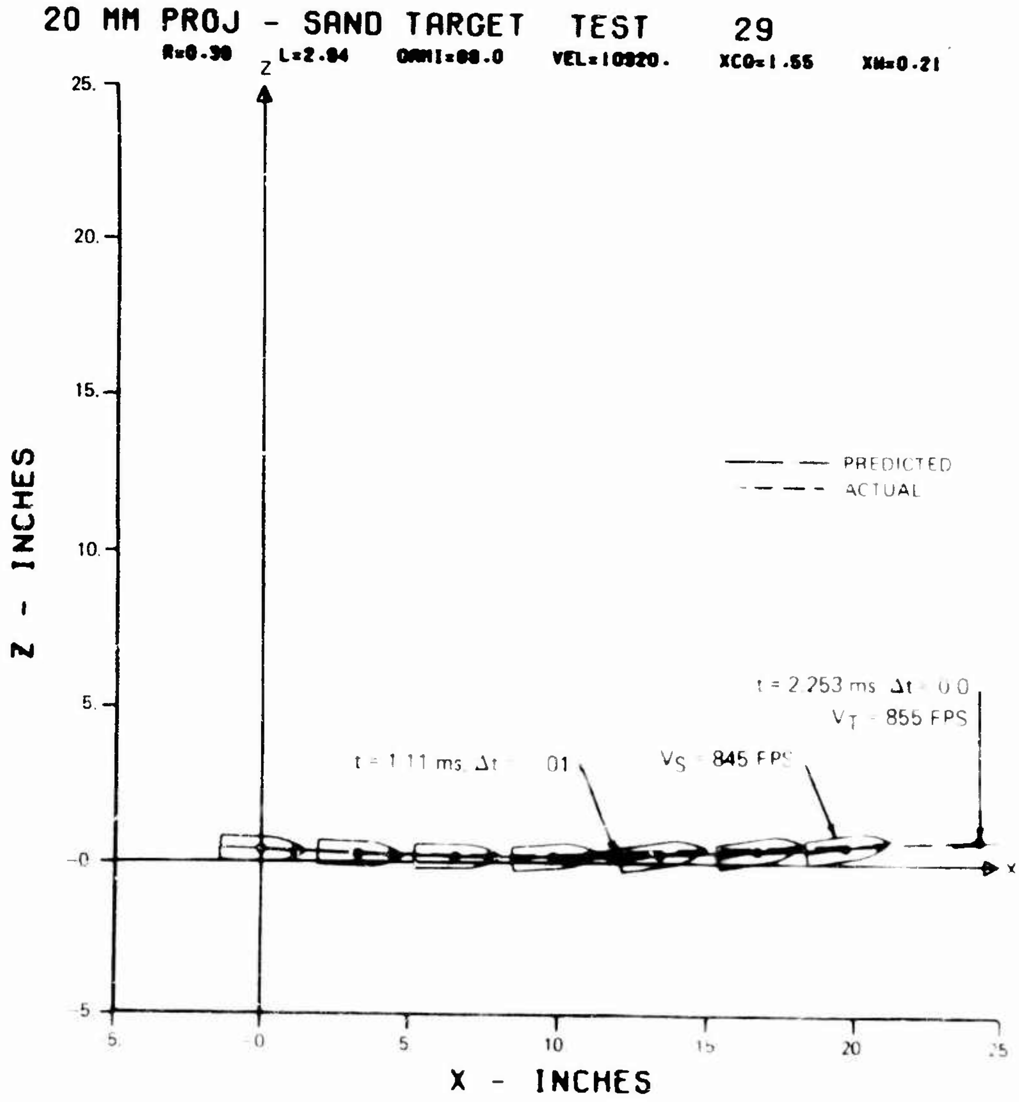

Figure I 4 SIMULATION RESULTS – TEST 29

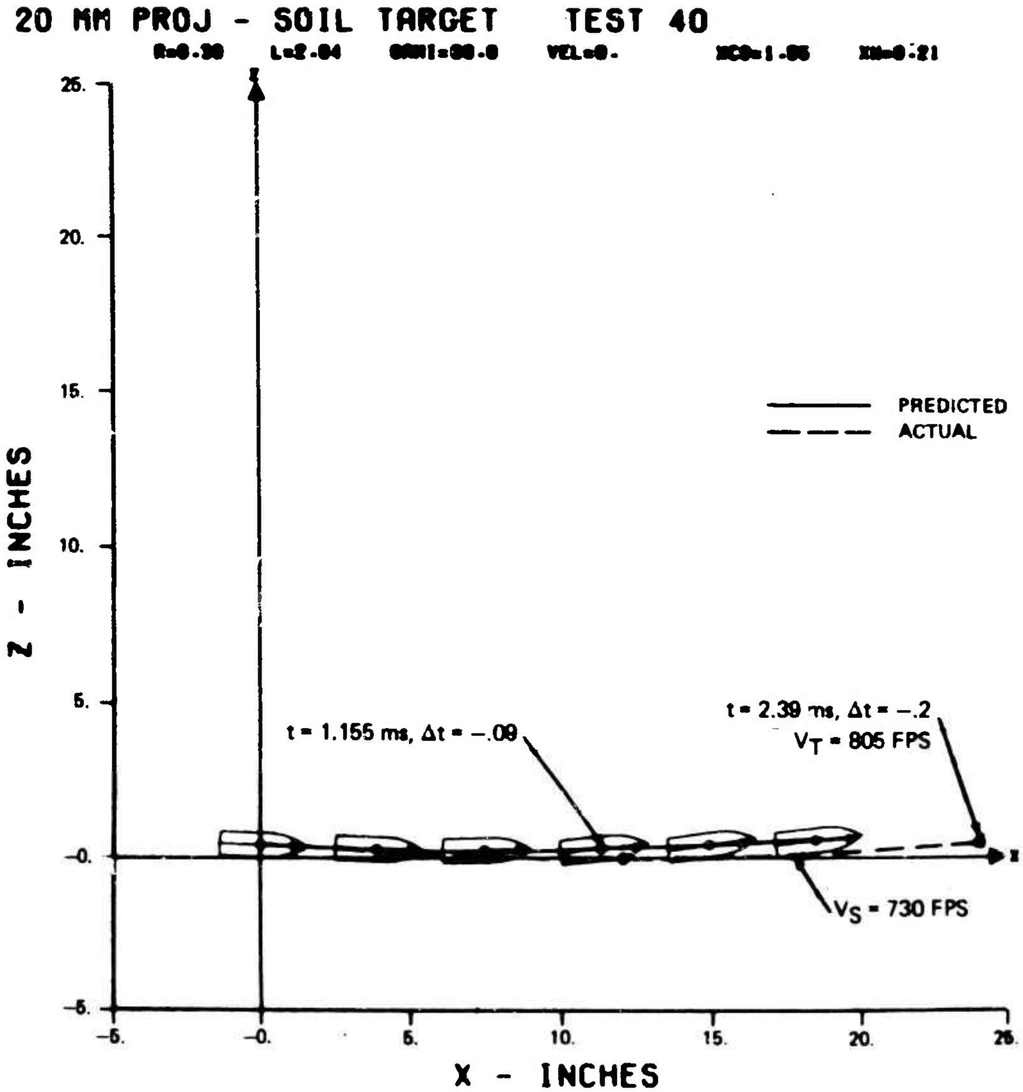

Figure I–5 SIMULATION RESULTS – TEST 40

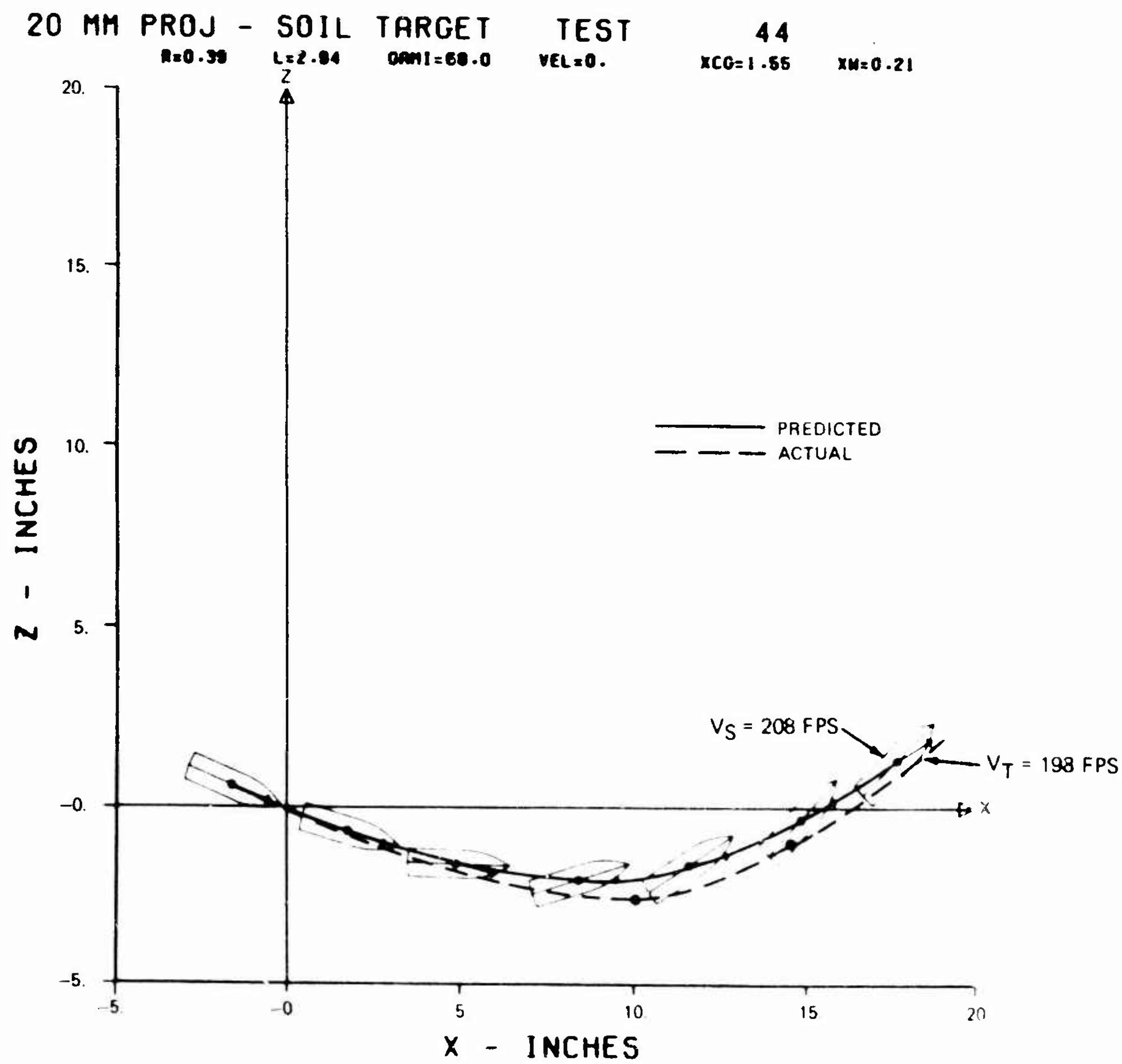

Figure I–6 SIMULATION RESULTS – TEST 44

APPENDIX II

TWO-DIMENSIONAL PENETRATION COMPUTER CODE

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INTRODUCTION

Figure II-1 depicts the general situation of an arbitrarily shaped projectile undergoing penetration into a resisting non-homogeneous media. Any analytical procedure which is developed for the purpose of predicting the trajectory and/or the loading distribution acting on the projectile during penetration must take into consideration all the pertinent conditions which influence those parameters. The obvious ones shown in Figure II-1 are:

1. Arbitrarily shaped projectile
2. Unsymmetrical and discontinuous loading due to
   a. non-homogeneous material
   b. discontinuous changes in material properties
   c. angle of attack
   d. flow separation and reattachment
   e. angular velocity
   f. instability
3. Obliquity

It is intended here to describe an approach and the analyses conducted for the purpose of generating a 2-dimensional impact and penetration simulator which solves the general penetration problem.

DISCUSSION

Most of the previous work on penetration has been concerned with normal impacts and homogeneous resisting media.

Due to symmetry, this impacting situation immediately eliminates a majority of the penetration complexities, namely asymmetrical loadings. Poncelet's equation (see Equation II-1) for predicting the axial loads acting on a projectile during normal impacts and penetration, through many different types of materials, has been demonstrated to be reasonably reliable.

$$F/A = \eta + CV^2 \qquad \text{(II-1)}$$

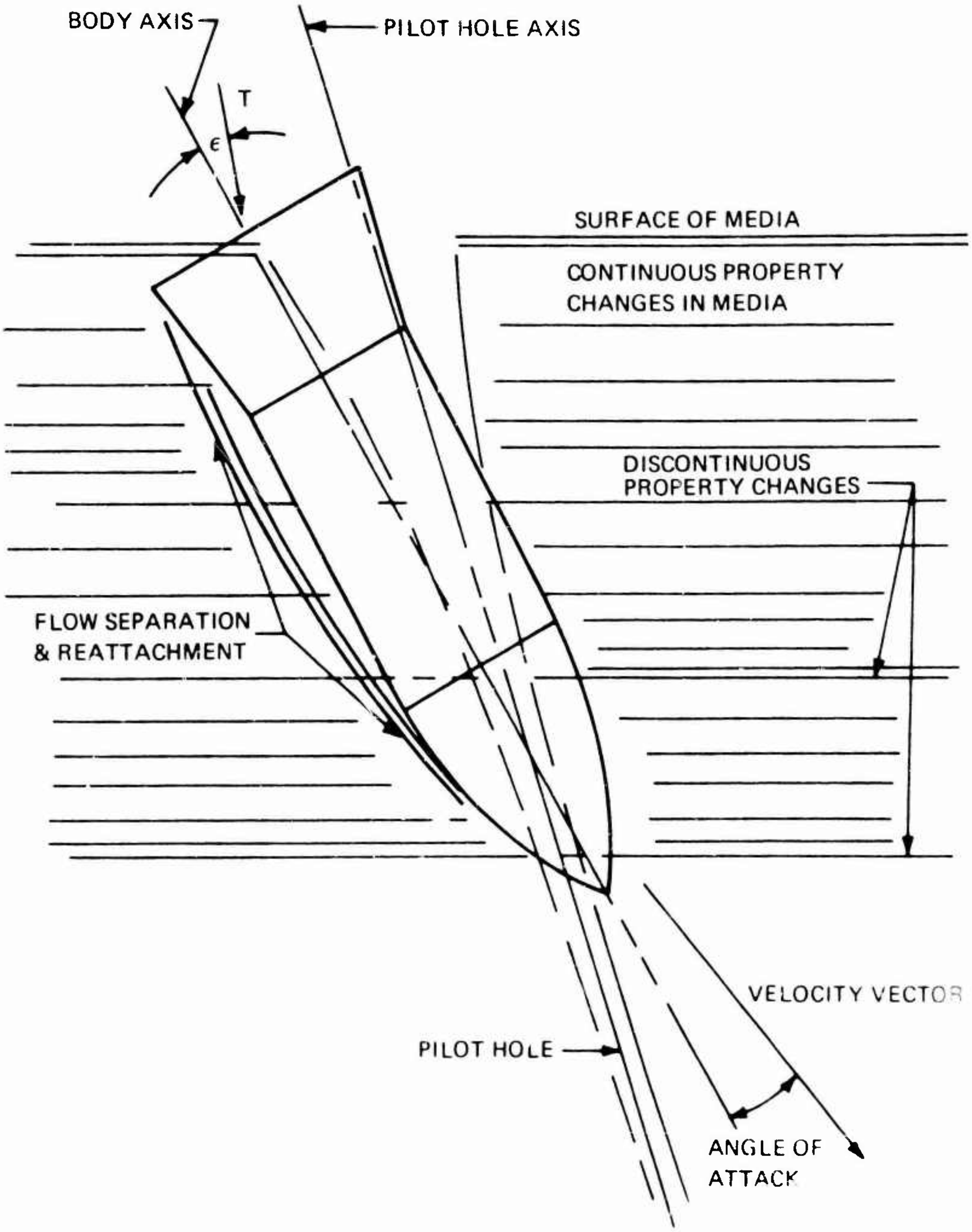

Figure II–1 GENERAL PENETRATION SITUATION

Several improvements have been suggested by investigators such as Allen, Mayfield and Morrison (Reference II-1) who determined that the relationships:

$$F/A = CV^2 \text{ for } V_o > V > V_c$$

and

$$F/A = \eta + CV^2 \text{ for } V_c > V > 0$$

where

V_o = impact velocity

V_c = critical velocity (apparently associated with the speed of sound in the media)

fit the data generated from a series of sand penetration tests better than Poncelet's. Figure II-2 presents some typical data that they generated which supports their contention. However, the difference between the above analytical representation and a modified version of Poncelet's, the power series in V (see Equation II-2) appears to be negligible.

$$F/A = \eta + BV + CV^2 \qquad \text{(II-2)}$$

These theories, however, are concerned primarily with predicting the resultant axial force acting on a projectile. The axial force, however, is only one component of the forces acting upon an elemental area. The other components, because of symmetry (in the case of normal impact), cancel one another.

It is also considerably easier to determine experimentally the axial acceleration and/or penetration depth of a projectile than to determine the pressure distribution, for example, around the surface of a projectile. Hence, less effort has been expended toward the understanding of these other force components.

The resistance to penetration force law to be incorporated in the 2-D simulator will be general in form, i.e.,

$$\frac{dF}{dA} = \text{Impact shock (compressibility effect)} + - - + \text{etc.}$$

The necessity of being able to define the forces acting on an individual element becomes apparent when considering other than normal impacts and penetrations. Oblique and angle-of-attack impacts or penetrations through non-homogeneous materials will result in non-cancellation of transverse forces, and the projectile will undergo two- or three-dimensional motion. For the penetration projectile designer, these transverse loads will mean combined axial and bending stresses and therefore a different emphasis on structural design. For the systems engineer, the curvilinear trajectories will mean more complex target analysis and projectile shape optimization.

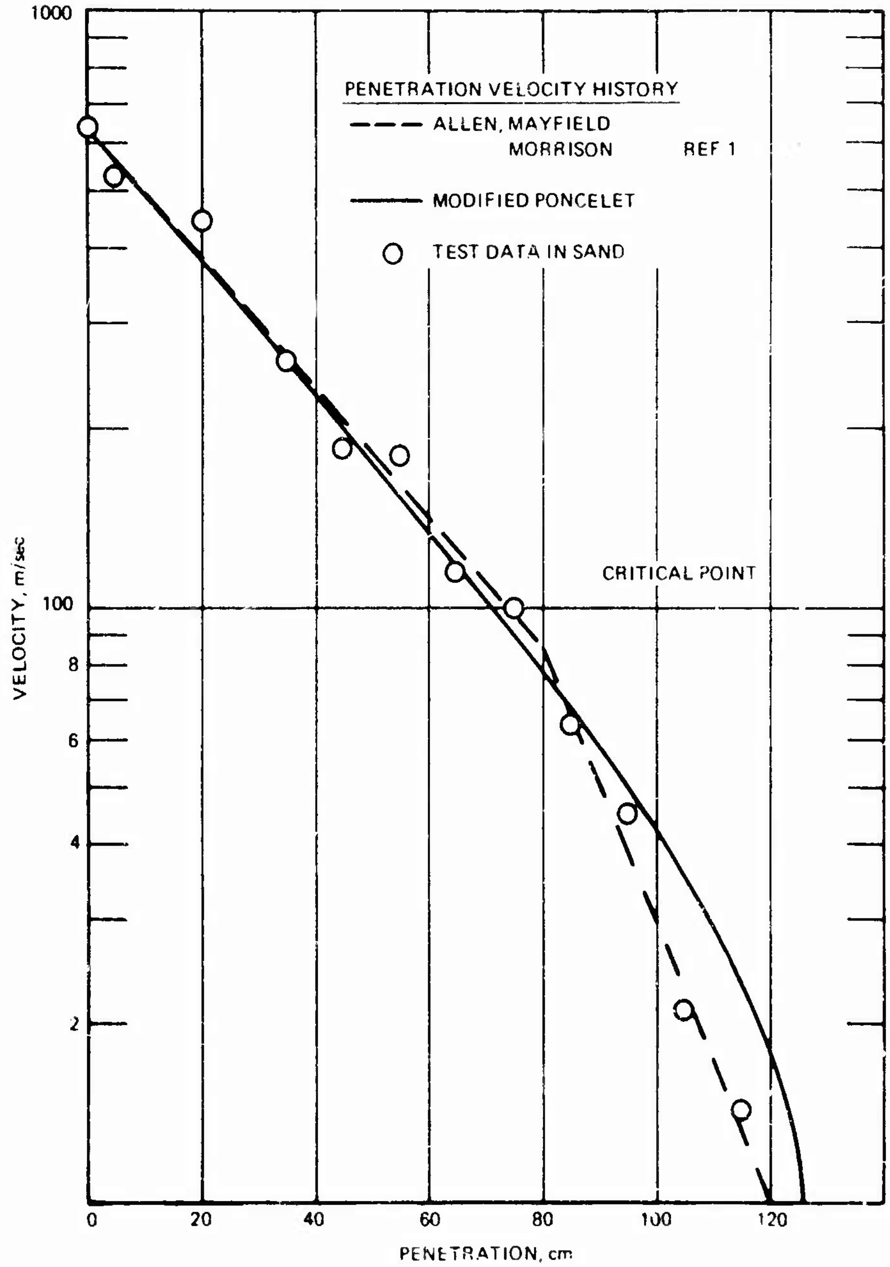

Figure II–2 PENETRATION VELOCITY HISTORY

In order to investigate these phenomena, the 2-D impact and penetration simulator has been developed. The code is used to predict:

1. The trajectory during penetration in a non-homogeneous media, i.e.,

    a. Linear changes of material properties with depth.

    b. Discontinuities of material properties at discrete depths.

2. The loading distribution over the entire surface area of the projectile.

3. The above phenomena for any body of revolution.

4. Flow separation and reattachment (The stability of a penetrating projectile can largely depend upon this characteristic.)

BASIC APPROACH

The complexity of the discontinuous loads and the desirability of determining the loading distribution acting on the projectile has led to the approach of dividing the projectile into elemental lengths and considering each length individually during penetration. The equations of motion are integrated numerically. The elemental lengths are fixed and can be represented by a truncated cone; consequently, the loading distribution around the truncated cone can be found by integrating the force law with respect to ϕ (the azimuth position of an elemental area dA) alone. The force on an elemental area dA is a defined function by the general force law. Discontinuous changes influence the loads acting on the position of the elemental length at each instant of time, solving the geometry of the position, thus determining the various limits on ϕ (representing location of the discontinuous changes) and performing multiple integrations of the force law. The total forces acting on the elemental length are determined by summing these results, and the total forces and moments acting on the projectile are the sum of the incremental forces and moments. This procedure is further defined in the subsequent section on the analysis.

ANALYSIS

Nomenclature

γ — angular position of projectile longitudinal axis relative to the inertial z-axis

$\theta(i)$ — incremental half-cone angle

ϕ — angular position of elemental area dA about z' axis ($\phi = 0$ along y')

η — is the theoretical structural resistance force required to pull a body through the resisting media; it acts in the direction of the velocity vector

B — a frictional coefficient (included for completeness) acting in the direction of the velocity vector

U	velocity vector
C_p	terradynamic pressure coefficient
C_τ	terradynamic shear coefficient
P	terradynamic pressure acting normal to the surface area
τ	terradynamic shear force acting along the projected velocity vector in the plane of the elemental area
ψ	angle between the velocity vector U and the plane of the elemental area dA
q	dynamic pressure $1/2\ \rho U^2$
α	angle of attack
$r(i)$	radius of elemental length
dL	elemental length
V_N	normal velocity component
ρ	density of resisting media (a function of depth)
M_{cg}	moment acting (on projectile) around the center of gravity
T	thrust
ϵ	thrust misalignment
w	projectile weight
β	rotation of inertial coordinate system from vertical
ω	projectile angular rate
Ne	number of elements

Coordinate System

A set of inertial coordinates x, y, and z are used to reference the motion and displacement of the projectile. The z-axis is normal to, and points away from, the plane of the media to be penetrated. The x-axis is parallel to the plane of the media, and the y-axis forms the orthogonal triad. The origin is located at the initial position of the center of gravity of the projectile (see Figure II-3).

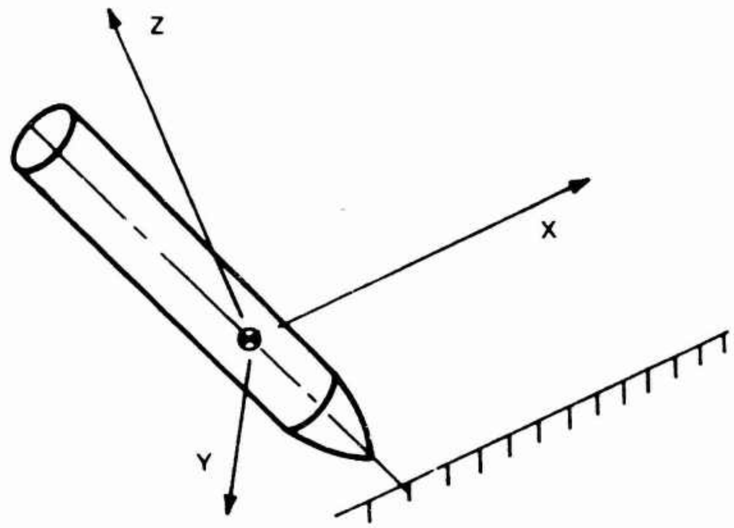

Figure II–3 INERTIAL COORDINATE SYSTEM

A body fixed set of coordinates x', y', and z' is used to orient the forces and moments acting on the body, and as only two-dimensional motion is considered, it is obtained in this use by a rotation γ about the y-axis (see Figure II-4).

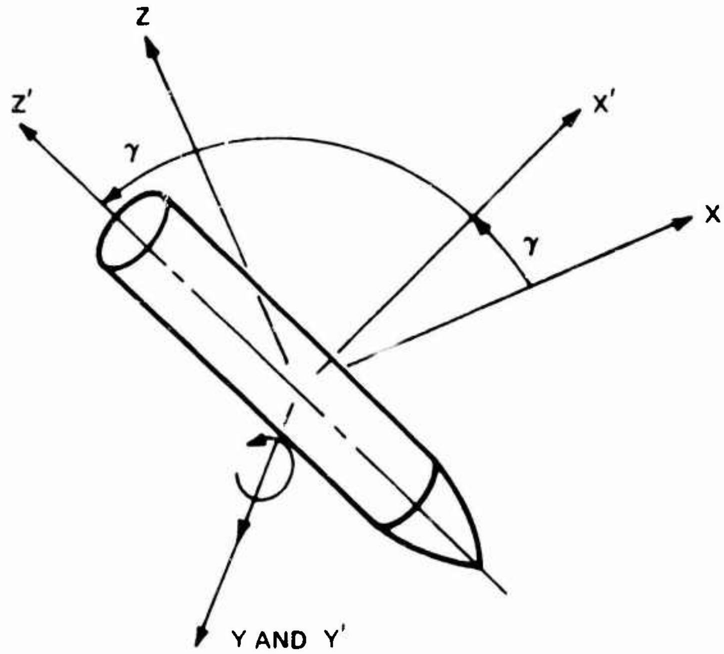

Figure II–4 BODY FIXED COORDINATE SYSTEM

The z' axis is directed aft along the longitudinal axis of the projectile, and the x' axis is in the plane of motion.

A third coordinate system is needed in which the elemental forces acting on the body are derived. This set, x''', y''', and z''', is obtained by two more rotations: ϕ , the azimuth position of an elemental area dA measured around the z' axis, and θ , the elemental half-cone angle of dA measured about the x'' axis as shown in Figure II-5.

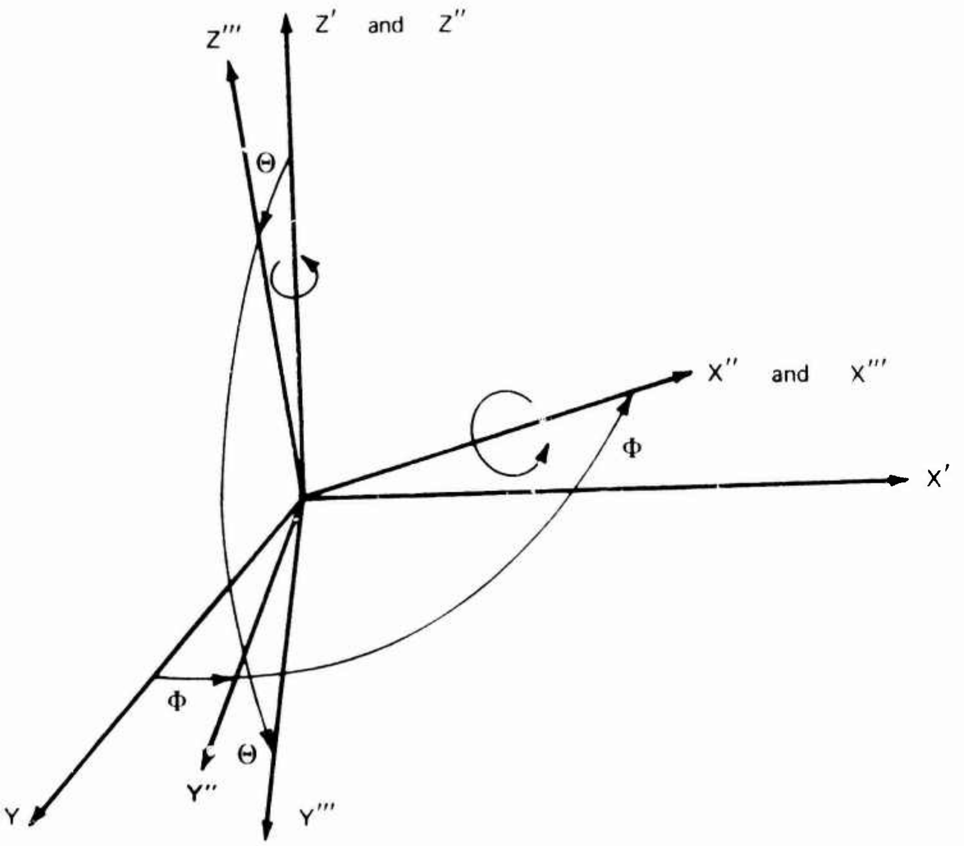

Figure II-5 ELEMENTAL FORCE COORDINATE SYSTEM

The y''' axis, therefore, is an axis normal to the elemental area dA while the x''' and z''' axes lie in the plane of the element.

The transformation matrix between the inertial set and the elemental set is:

$$\begin{vmatrix} z''' \\ x''' \\ y''' \end{vmatrix} = \begin{Vmatrix} C\theta\, C\gamma + S\theta\, S\phi\, S\gamma & -C\theta\, S\gamma + S\theta\, S\phi\, C\gamma & S\theta\, C\phi \\ C\phi\, S\gamma & C\phi\, C\gamma & -S\phi \\ -S\theta\, C\gamma + C\theta\, S\phi\, S\gamma & S\theta\, S\gamma + C\theta\, S\phi\, C\gamma & C\theta\, C\phi \end{Vmatrix} \begin{vmatrix} z \\ x \\ y \end{vmatrix} \qquad \text{(II-3)}$$

where the C's and S's represent cosines and sines, respectively.

Force Law

The forces acting upon an elemental surface area are:

$$dF/dA = \eta \leftrightarrow BU \leftrightarrow CU^2 \quad \text{(II-4)}$$

$$dF = \eta dA_p \leftrightarrow BU\, dA_p \leftrightarrow dP \leftrightarrow d\tau \quad \text{(II-5)}$$

where:

$$dP = C_p \sin^2 \psi \, q \, dA$$

$$d = C_\tau \sin \psi \cos \psi \, q \, dA$$

as derived in Reference II-3.

In the body frame, the transverse force function is:

$$dFx' = \eta \sin \alpha \, dA_p + BU \sin \alpha \, dA_p \quad \text{(II-6)}$$

$$dP \sin \phi \cos \theta + d\tau \cos \xi \cos \phi$$

and the axial force function is:

$$dFz' = \eta \cos \alpha \, dA_p + BU \cos \alpha \, dA_p - dP \sin \theta + d\tau \sin \xi \cos \theta \quad \text{(II-7)}$$

or

$$dFx' = \sum_{i=1}^{4} dFx' \ (i) \quad \text{(II-8)}$$

$$dFz' = \sum_{i=1}^{4} dFx' \ (i) \quad \text{(II-9)}$$

In view of the approach to divide the projectile into elemental lengths, the elemental area is:

$$dA = r(i) \, dL/\cos \theta (i) \, d\phi \quad \text{(II-10)}$$

the projected area (on a plane perpendicular to the velocity vector) is:

$$dA = dA \sin (\theta \, \alpha \sin \phi) \quad \text{(II-11)}$$

Normally, penetration where large angles of attack are produced are of no interest; therefore assuming small results in:

$$dFx'(1) = \eta(\sin\phi + \cos\theta \sin\phi\alpha) \sin\alpha \, dA \tag{II-12}$$

Substituting and performing the indicated integration with respect to ϕ gives

$$Fx'(1) = Ax_1(\phi_2 - \phi_1) - Bx_1(\cos\phi_2 - \cos\phi_1) \tag{II-13}$$

where Ax_1 and Bx_1 are functions of η, r, ΔL, θ, and α and projectile geometry.

Similarly:

$$Fx'(2) = U[Ax_2(\phi_2 - \phi_1) - Bx_2(\cos\phi_2 - \cos\phi_1)] \tag{II-14}$$

The terms $Fx'(3)$ and $Fx'(4)$ contain ρ and ψ, both functions of ϕ.

$$dFx'(3) = C_p \sin^2\psi \; 1/2\, \rho U^2 dA \tag{II-15}$$

but

$$U^2 \sin^2\psi = V_N^2 = (\dot{y}''')^2$$

and from Eq. II-1

$$V_N = (S\phi\, S\gamma - C\phi\gamma\, S\phi)\dot{z} + (-S\phi\, S\gamma + C\theta\, C\gamma\, S\phi)\dot{x} \tag{II-16}$$

and assuming ρ is a linear variation with depth leads to:

$$\rho = A_p + B_p \sin\phi \tag{II-17}$$

where A_p and B_p are functions of the projectile geometry and γ.

Substituting and performing the indicated operations results in:

$$Fx'(3) = F\cos\theta \Big\{ -A_p(\cos\phi - \cos\phi) \tag{II-18}$$

$$+ B_p\left[\frac{\phi_2 - \phi_1}{2} \quad \frac{\sin^2\phi_2 - \sin^2\phi_1}{4}\right]$$

$$+ C_p\left[\cos\phi_1 - \cos\phi_2 + (\cos^3\phi_2 - \cos^3\phi_1)^{1/3}\right]$$

$$+ D_p\left[\frac{3(\phi_2 - \phi_1)}{8} - \frac{3}{16}(\sin\phi_2 - \sin\phi_1\right]$$

$$- 1\,4(\sin^3\phi_2\cos\phi_2 - \sin^3\phi_1\cos\phi_1)\Big\}$$

where the coefficients are again functions of C_p, r, ΔL, θ, a, $\dot{z}$, $\dot{x}$, ω, C_r and projectile geometry.

$$dFx'(4) = C_r \sin\psi \cos\psi \, 1/2 \, \rho U^2 \cos\xi \cos\phi \, dA \qquad \text{(II-19)}$$

but

$$\cos\xi = \frac{\dot{x}'''}{U\cos\psi}$$

and

$$U \sin\psi = V_N = \dot{y}'''$$

$$\dot{x}''' = C\phi \, S\gamma \dot{z} + C\phi \, C\gamma \dot{x}$$

Substituting and integrating leads to a form similar to Eq. (II-18) but with different coefficients. In the same manner, the expression for $Fz\,(i)$ can be obtained.

For each force term, the integration limits $\phi\,(i)$'s are obtained as a function of:

1. Discontinuities in the resisting media.

2. Pilot hole geometry and location.

3. Where the normal velocity component V_N goes to zero (see Figure II-6).

The total force acting on each element of length is then the sum of the forces for each set of integration limits, while the resultant forces acting on the projectile is the sum of the forces acting on each element.

In the inertial coordinate system:

$$Fx = -\sum_{n=1}^{Ne} Fz'(n)\sin\gamma + \sum_{n=1}^{Ne} Fx'(n)\cos\gamma + W\sin\beta + T\sin\epsilon\cos\gamma \qquad \text{(II-20)}$$

$$Fz = \sum_{n=1}^{Ne} Fz'(n)\cos\gamma + \sum_{n=1}^{Ne} Fx'(n)\sin\gamma + W\cos\beta + T\cos\epsilon\sin\gamma \qquad \text{(II-21)}$$

$$M_{cg} = \sum_{n=1}^{Ne} [s(n)^{\bullet} Fx'(n)] + T\sin\epsilon^{\bullet} d \qquad \text{(II-22)}$$

The equations of motion:

$$M\ddot{x} = F_x$$

$$M\ddot{z} = F_z$$

$$I\ddot{\gamma} = M_{cg}$$

are numerically integrated.

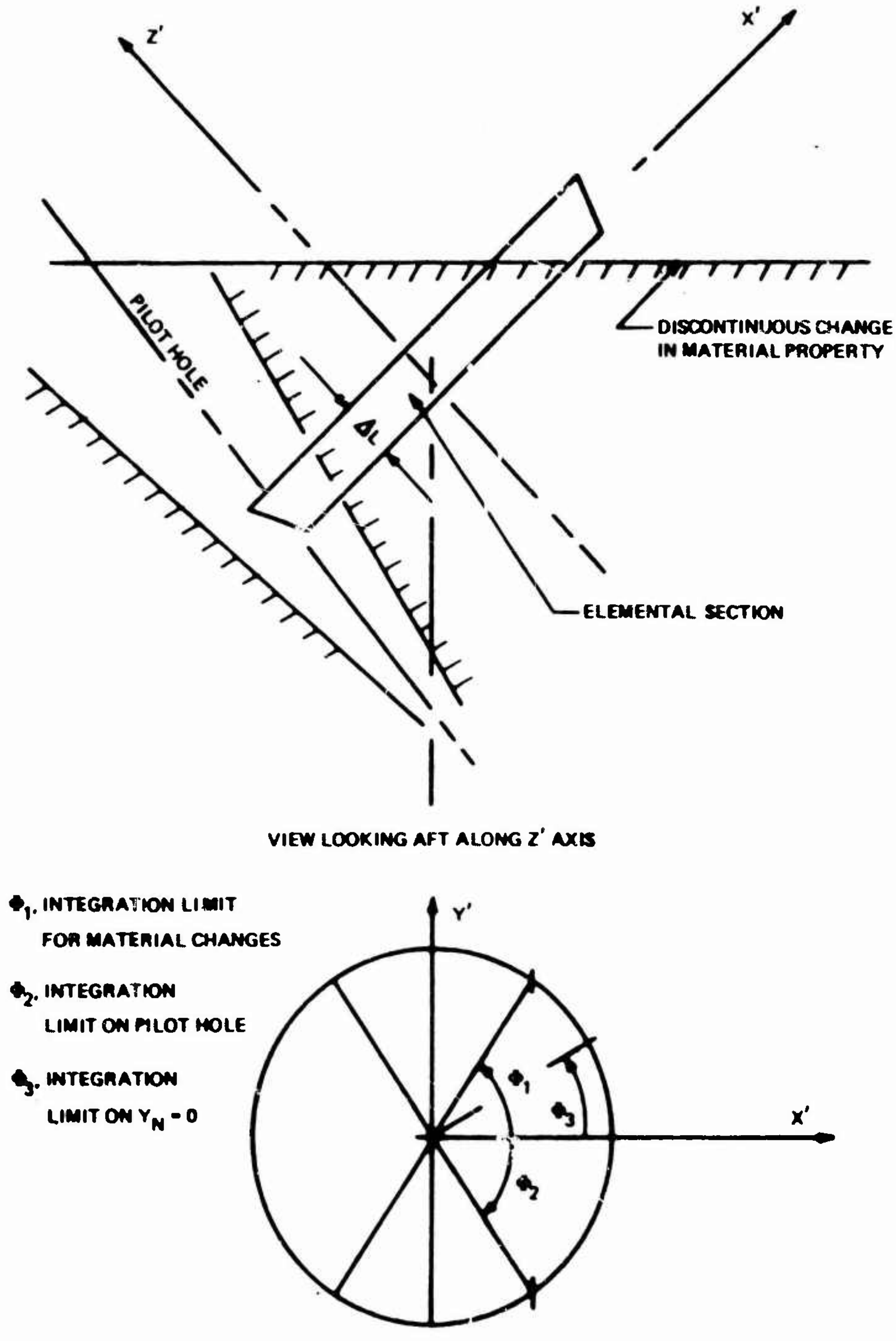

Figure II–6 INTEGRATION LIMIT DETERMINATION

REFERENCES

II-1. Allen, W. A., Mayfield, E. B. and Morrison, H. L., "The Dynamics of Projectile Penetration in Sand", NAVORD 4980, U. S. Naval Ordnance Test Station (China Lake, California), December 7, 1955.

II-2. RP/V Program Terradynamics Report, January 31, 1964, Avco/RAD (S).

II-3. Hayes, W. D., Probstein, R. F., "Hypersonic Flow Theory", 1959, pg. 404.

APPENDIX III

PROGRAM 2947: STRUCTURAL RESPONSE CODES AND INTEGRATION ROUTINES

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Program 2607

The dynamic models of complex structures can be formulated by finite element and/or lumped parameter techniques. The resultant equations of equilibrium of motion are second order simultaneous, differential equations in generalized coordinates.

A digital computer program has been written to compute the eigen values, eigen vectors, and modal damping matrix of the system (up to 150 degrees of freedom) and is registered in the Avco Mathematics Department under the code designation 2607. The eigen value and eigen vector routine used is a modified Householder-Givens routine (designated as the HOUSE routine).

Modal analysis is an important technique for computing the transient and steady state dynamic responses for any linear physical system. In its application to matrix methods of structural mechanics, where the mathematical model of a continuous structure can be formulated as the assembly of discrete elements, with its stiffness matrix (K) and mass matrix (M) computed by the finite element displacement method, the resulting linear system is

$$(M)(\ddot{x}) + (K)(x) = (F(t)).$$

In the solution of this linear system of second order equations by the modal method, it is very important to compute accurately the eigen values and eigen vectors. The main purpose of the Avco/IBM program 2607 is to compute the frequencies and mode shapes, utilizing the best current technique possible.

It has been demonstrated that the finite element method (based upon the principle of minimum potential energy) will yield solutions which converge to the exact solutions when the sizes of the finite elements are progressively reduced. Therefore, a fast routine to compute accurately the eigen values and eigen vectors of a large ($n \times n$) real symmetric matrix associated with the homogeneous system $(M)(\ddot{x}) + (K)(x) = 0$ is highly desirable. Based upon past experiences and comparisons made with Avco Computer Program 1384 series and the FAMOUS Program of MIT, the most satisfactory routine based upon a modified Givens-Householder method has been chosen as the basic routine for Avco Computer Program 2607.

Upon determination of the eigen values, vectors and generalized damping matrix, the linear decoupled equations of modal motion could be solved under conditions of an applied generalized forcing function. This approach, however, presumes linearity which is generally not the case for projectile impact problems. For this situation, the above produced modal damping matrix is used and the coupled non-linear equations of motion are solved with the use of Program 1520 described in the next paragraph.

Program 2947

Dynamic analysis of missile structures (DAMS) is a program to solve numerically the generalized coordinate system of second-order, ordinary linear or nonlinear differential equations in the frequency range of structural models. The program was designed primarily to calculate transient responses of missile structures but may be used for other mechanical or electrical systems.

The system of equations to be solved is:

$$a_{11}\ddot{x}_1 + \cdots + a_{1n}\ddot{x}_n + b_{11}\dot{x}_1 + \cdots + b_{1n}\dot{x}_n + c_{11}\dot{x}_1 + \cdots c_{1n}x_n$$
$$= f_1(t, \dot{x}_1, \cdots, x_n, x_1, \cdots, \dot{x}_n)$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$

$$a_{n1}\ddot{x}_1 + \cdots + a_{nn}\ddot{x}_n + b_{n1}\dot{x}_1 + \cdots + b_{nn}\dot{x}_n + c_{n1}x_1 + \cdots c_{nn}x_n$$

$$= f_n(t, x_1, \cdots, x_n, \dot{x}_1, \cdots \dot{x}_n)$$

where a_{ij}, b_{ij}, c_{ij} are constants, the x_i's are the coordinates of the system, and the f_i's are arbitrary single-valued functions (linear or nonlinear). Written in the matrix form of:

$$A\ddot{X} + B\ddot{X} + CX = F(T, X, \dot{X})$$

where

$$A = \begin{bmatrix} a_{11}\, a_{12} \cdots & a_{1n} \\ a_{21}\, a_{22} \cdots & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ a_{n1} & a_{nn} \end{bmatrix} \quad B = \begin{bmatrix} b_{11}\, b_{12} \cdots & b_{1n} \\ b_{21} \cdots\cdots & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ b_{n1} & b_{nn} \end{bmatrix} \quad C = \begin{bmatrix} c_{11}\, c_{12} \cdots & c_{1n} \\ c_{21} \cdots\cdots & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \\ c_{n1} & c_{nn} \end{bmatrix}$$

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix}, \quad \dot{X} = \begin{bmatrix} \dot{X}_1 \\ \dot{X}_2 \\ \cdot \\ \cdot \\ \cdot \\ \dot{X}_n \end{bmatrix}, \quad \ddot{X} = \begin{bmatrix} \ddot{X}_1 \\ \ddot{X}_2 \\ \cdot \\ \cdot \\ \cdot \\ \ddot{X}_n \end{bmatrix}, \quad F = \begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_n \end{bmatrix}$$

The unique features of DAMS are the flexibility of analytically describing the forcing function; the specification of additional user-desired calculation and outputs by the users' own subroutines, and the graphical outputs that consist of displacement, velocity, acceleration, forcing function, and any user-specified function. As a minimum, the user only needs to specify the forcing function and other pertinent quantities peculiar to the differential equations. The outputs for this minimum input will be displacement, velocity, acceleration, and forcing function at each time step.

DDM4RK - INITIAL VALUE INTEGRATION ROUTINE

Solutions to initial value ordinary differential equations are frequently required in the work currently being done at the contractor facility. The method most often used is the fourth order Adams predictor-corrector technique as implemented in our library subroutine ADM4RK.

Method

A system of ordinary differential equations is numerically solved using an Adams predictor-corrector method. The predictor is an estimate of the function based on the value of the function at the last point and the values of the derivative at the last four points. The corrector is an estimate of the function based on the value of the function at the last point and the values of the derivative at the predictor and the last three points. The difference between the predictor and corrector is a measure of the error at a given step and this fact is used to vary the interval of integration for optimum performance.

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APPENDIX IV

MK82 FUZE ACCELERATION

IMPACT ENVIRONMENT

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TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD

(Axial Response) Sand Impacts

Time Regime 0.0 - 1.5 Milliseconds

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	13,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
30			
35			
40			
45			
55			
60			
65			
70	13,200	24 - Aft Fuze	
20	10,800	26 - Forward Fuze	
25			
35			
40			
45			
55			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
35			
40			
45			
55			
65			
70	10,800	24 - Aft Fuze	Acceleration

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Cont'd)

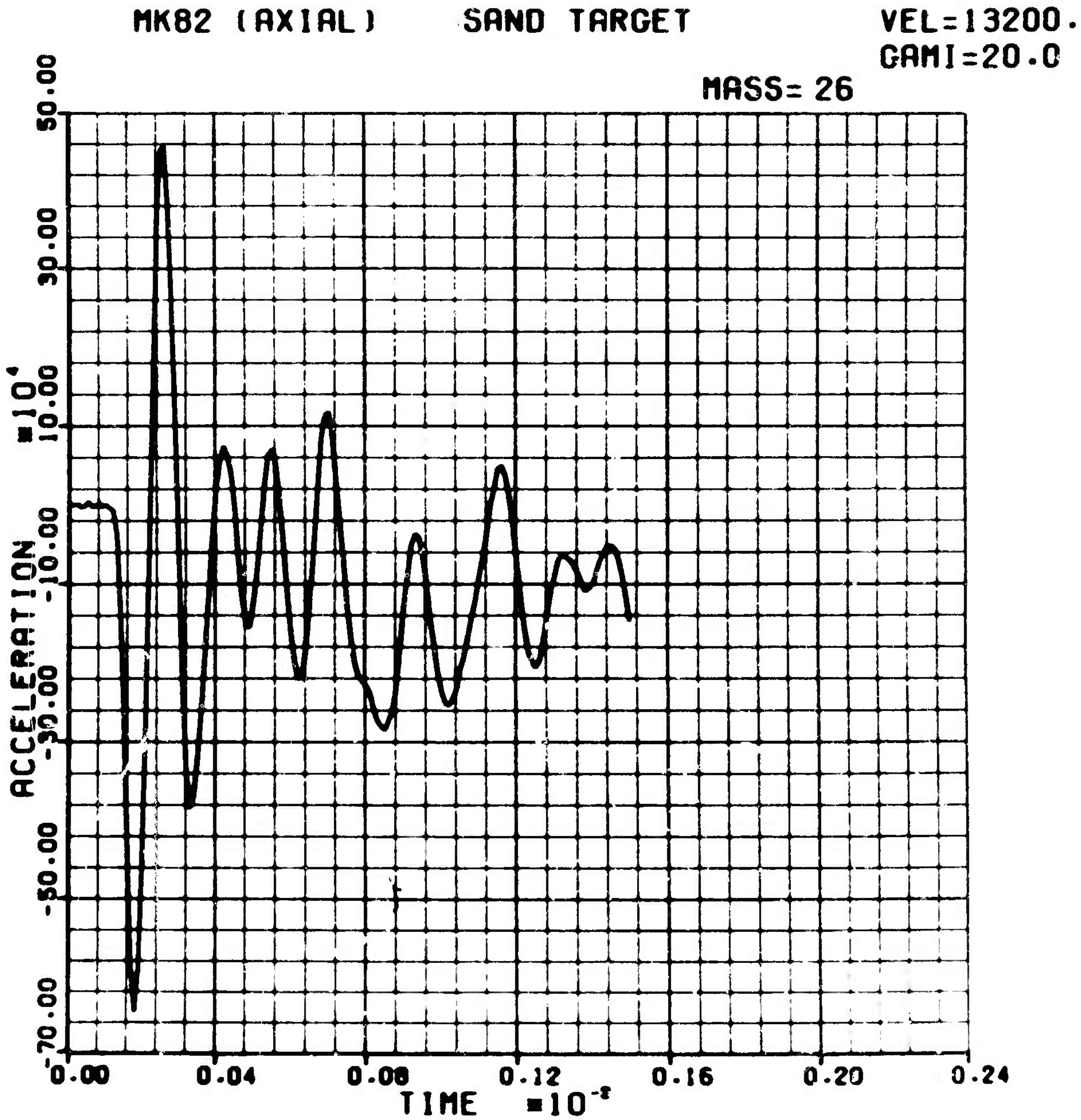
Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	26 - Forward Fuze	Acceleration
25			
30			
35			
40			
45			
55			
60			
65			
70		26 - Forward Fuze	
20		24 - Aft Fuze	
25			
30			
35			
45			
55			
65			
70	7,200	24 - Aft Fuze	Acceleration
		(Lateral Response)	
20	13,200	5 - Forward End of Forward Fuze	Acceleration
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70			
20		43 - Aft End of Forward Fuze	
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70	13,200		Acceleration

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Cont'd)

Impact Conditions γ ~deg	Impact Conditions V ~In./sec	Station	Response Data
20	13,200	39 - Aft End of Aft Fuze	Acceleration
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70	13,200		
20	10,800	5 - Forward End of Forward Fuze	
25			
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70			
20		43 - Aft End of Forward Fuze	
25			
35			
45			
55			
65		43 - Aft End of Forward Fuze	
70			
20		41 - Forward End of Aft Fuze	
25			
35			
45			
55			
65		41 - Forward End of Aft Fuze	
70			
20		39 - Aft End of Aft Fuze	
25			
35			
45			
55			
65		39 - Aft End of Aft Fuze	
70	10,800		
20	7,200	5 - Forward End of Forward Fuze	
25			
35			
45			
55			
65		5 - Forward End of Forward Fuze	
70	7,200		Acceleration

TABLE IV-I. FUZE ENVIRONMENT SUMMARY MK82 WARHEAD (Concl'd)

Impact Conditions		Station	Response Data
γ ~deg	V ~In./sec		
20	7,200	43 - Aft End of	Acceleration
25		Forward Fuze	
35			
45			
55			
65		43 - Aft End of	
70		Forward Fuze	
20		41 - Forward End of	
25		Aft Fuze	
35			
45			
55			
65		41 - Forward End of	
70		Aft Fuze	
20		39 - Aft End of	
25		Aft Fuze	
35			
45			
55			
65		39 - Aft End of	
70	7,200	Aft Fuze	Acceleration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SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 26
ACCELERATION *10⁴
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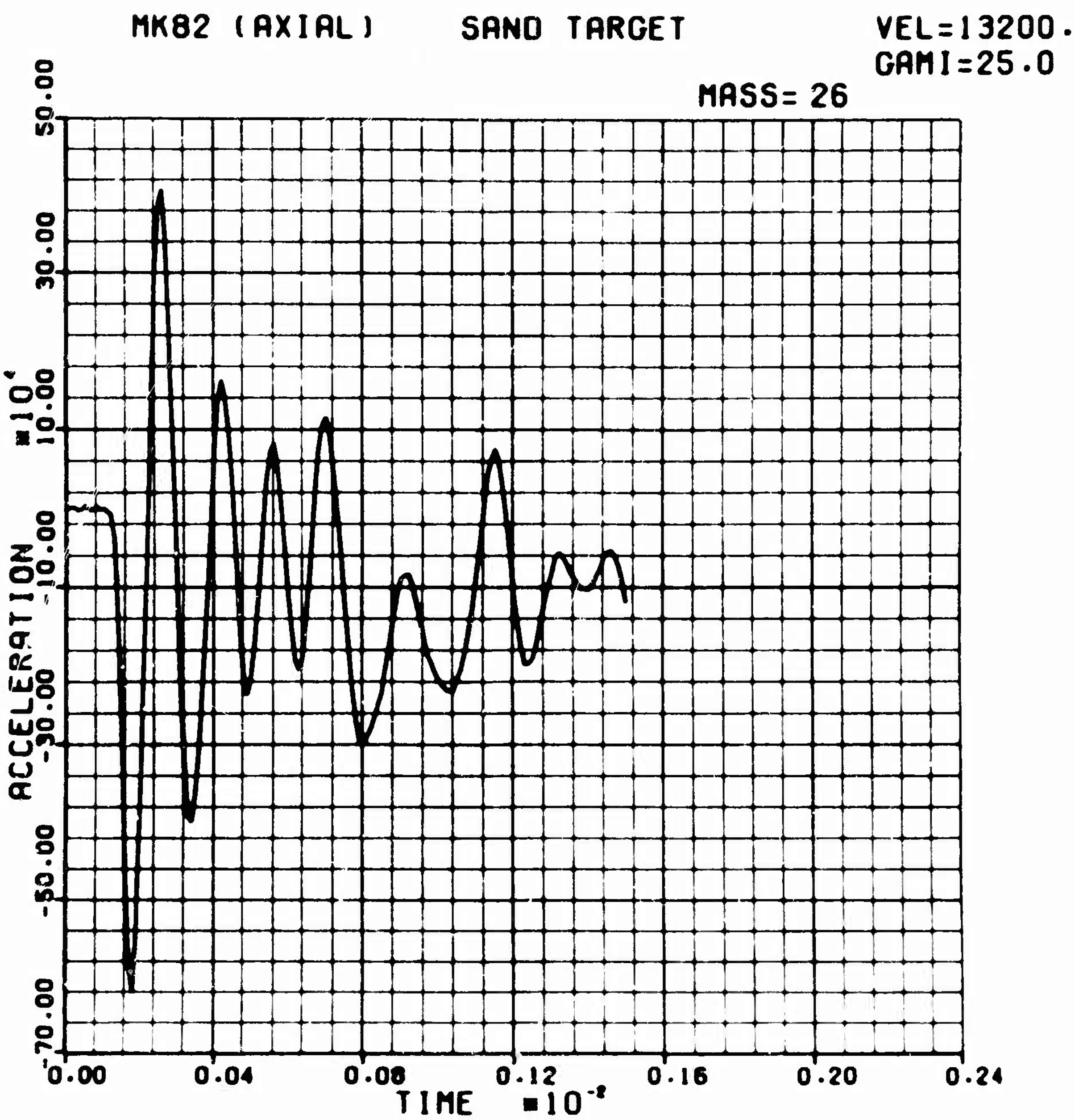
30.00
10.00
-10.00
-30.00
-50.00
-70.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²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SAND TARGET
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GAMI=25.0
MASS= 26
ACCELERATION *10^4
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10.00
-10.00
-30.00
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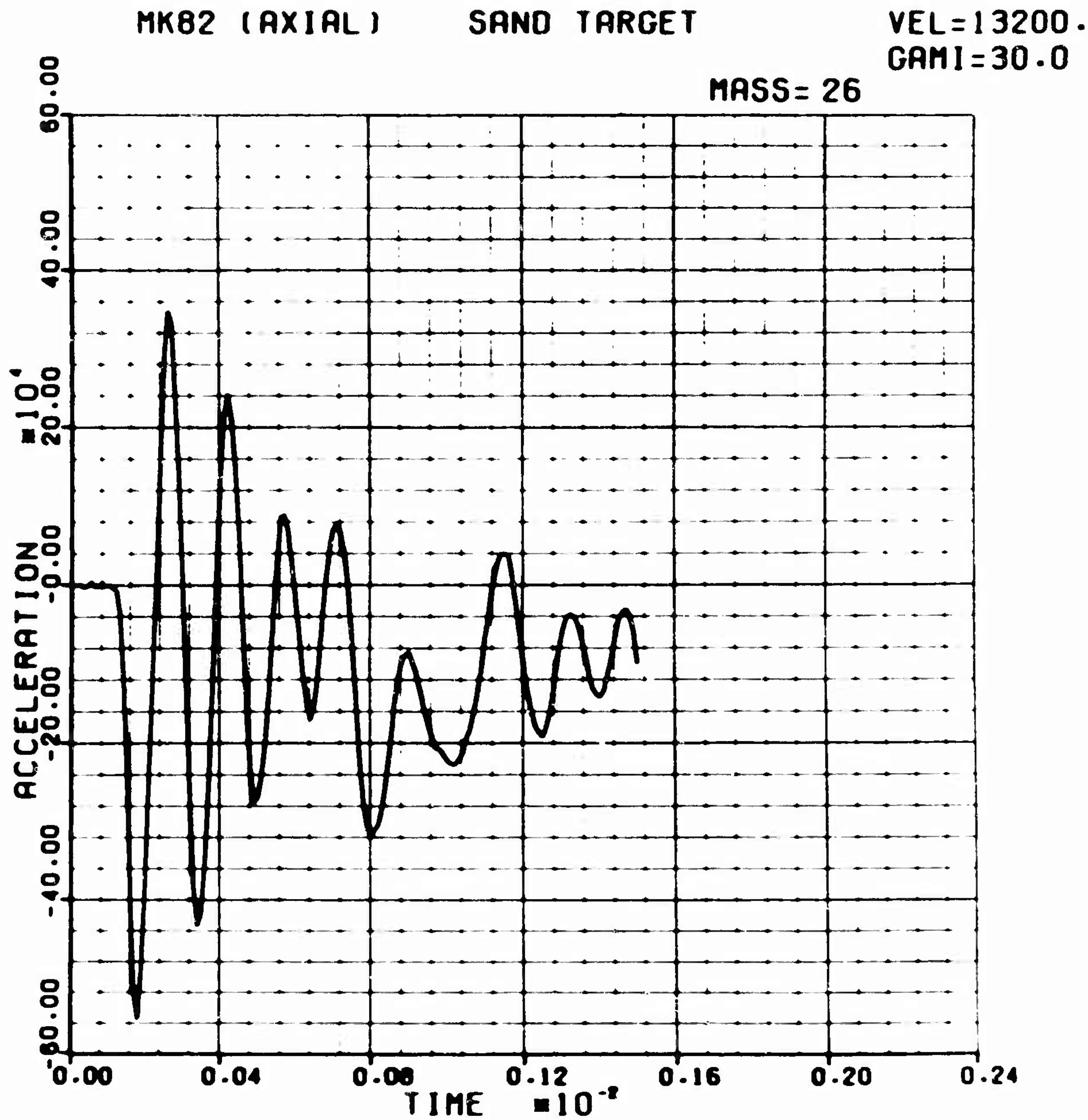
-70.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2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SAND TARGET
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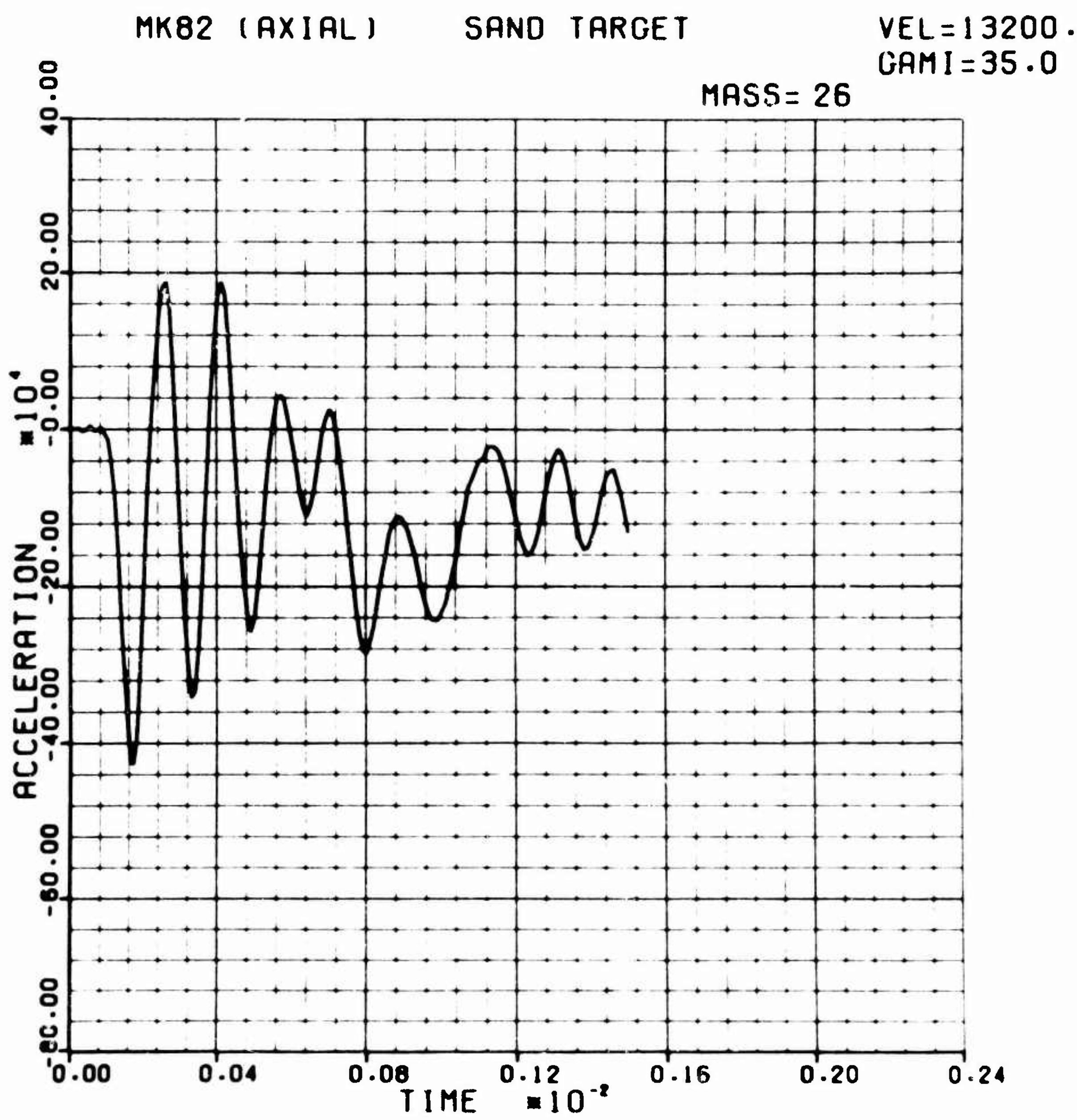
GAMI=30.0
MASS= 26
ACCELERATION ×10⁴
60.00
40.00
20.00
-0.00
-20.00
-40.00
-60.00
TIME ×10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24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SAND TARGET
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GAMI=35.0
MASS= 26
ACCELERATION *10⁴
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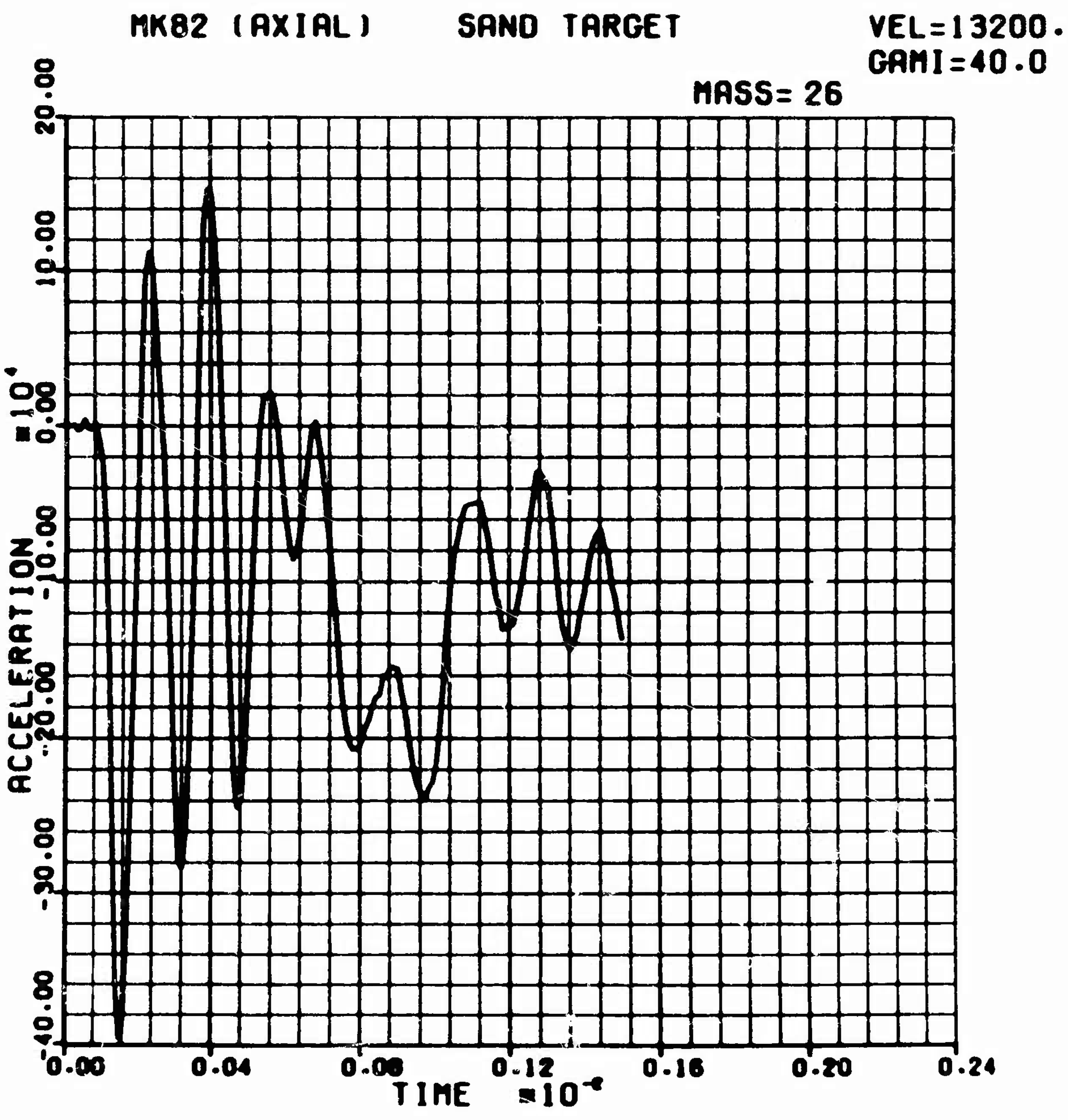
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



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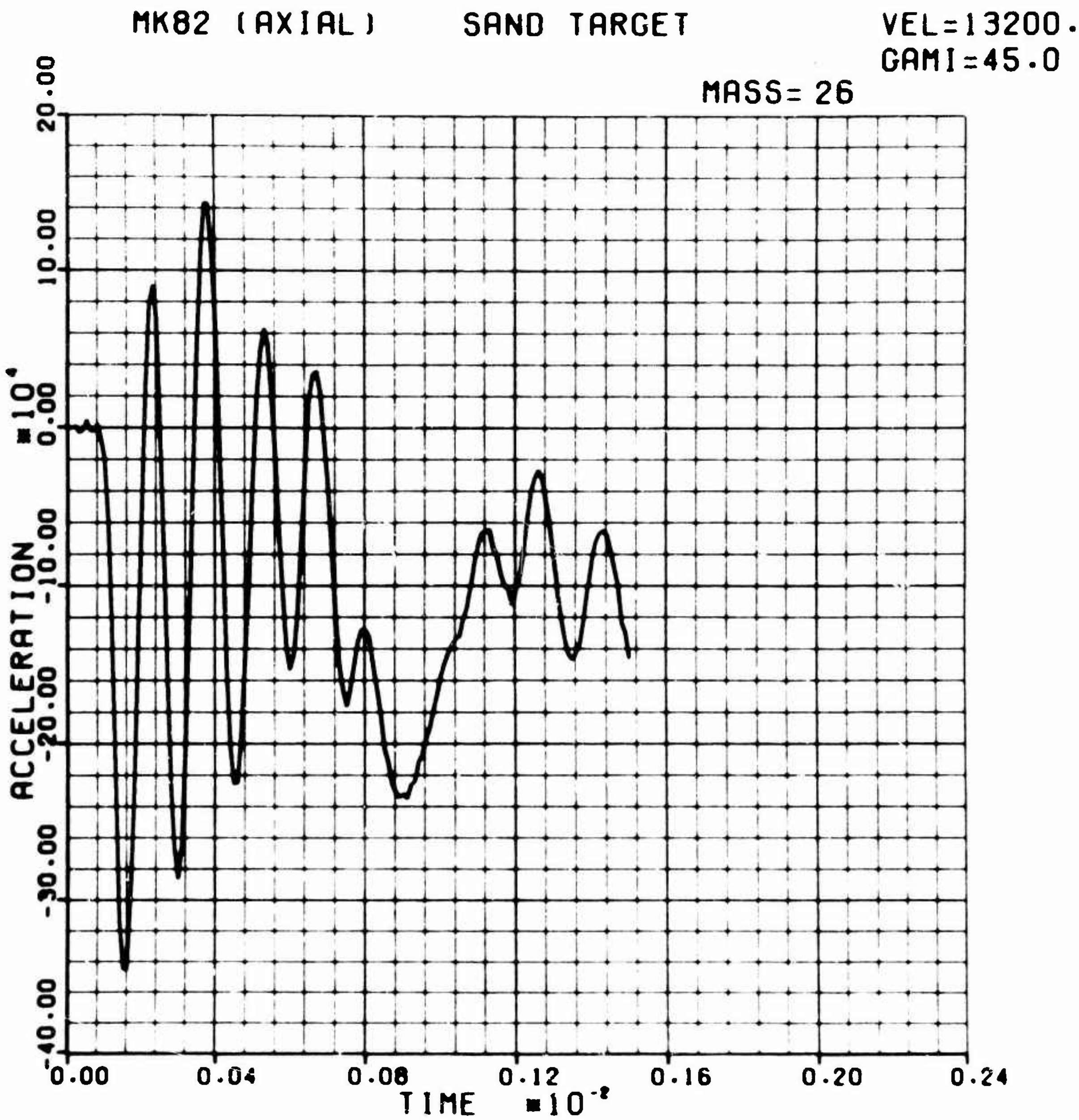
SAND TARGET
VEL=13200.
GAMI=40.0
MASS= 26
ACCELERATION *10⁴
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24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GAMI=45.0
MASS= 26
ACCELERATION *10^4
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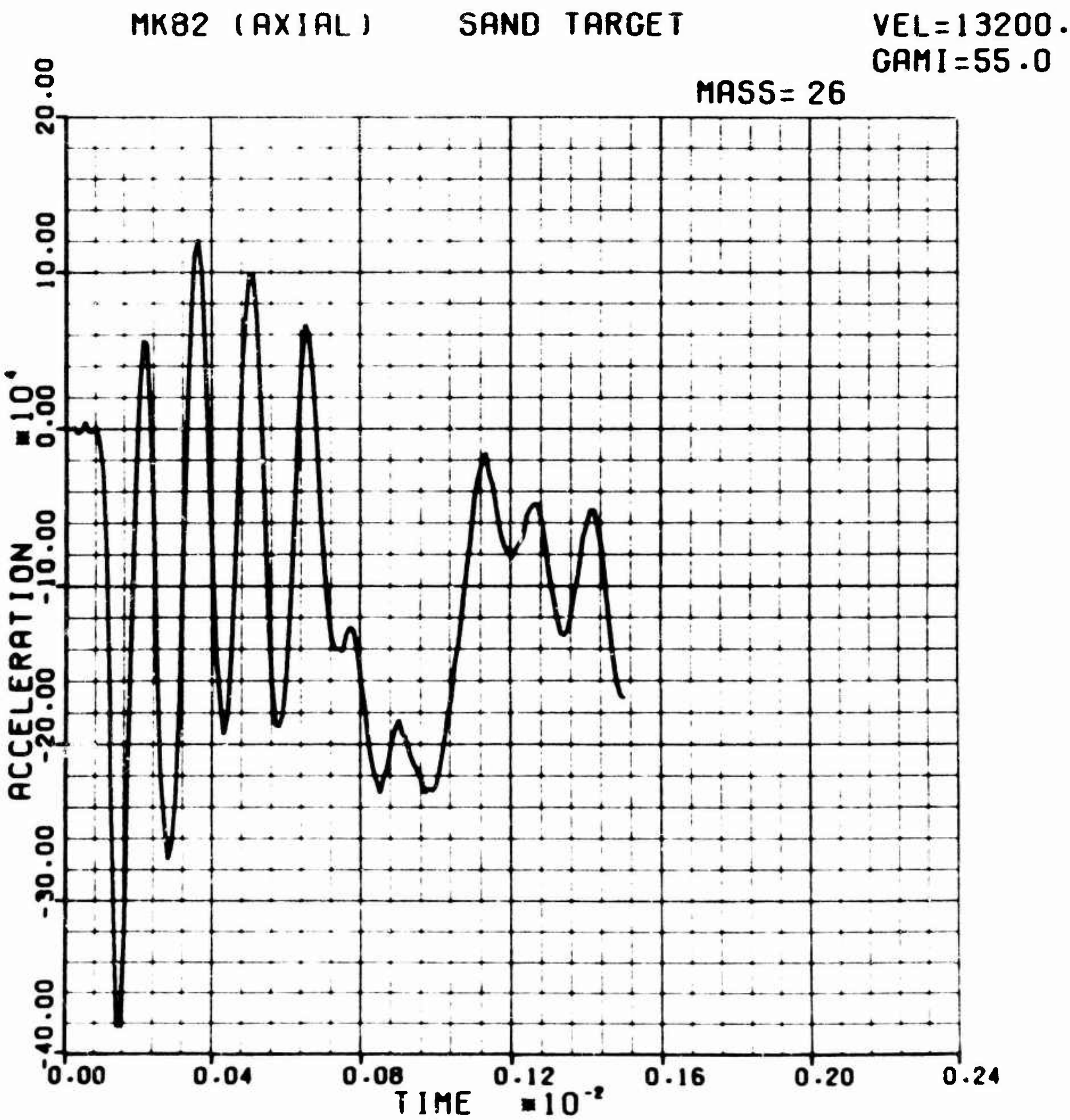
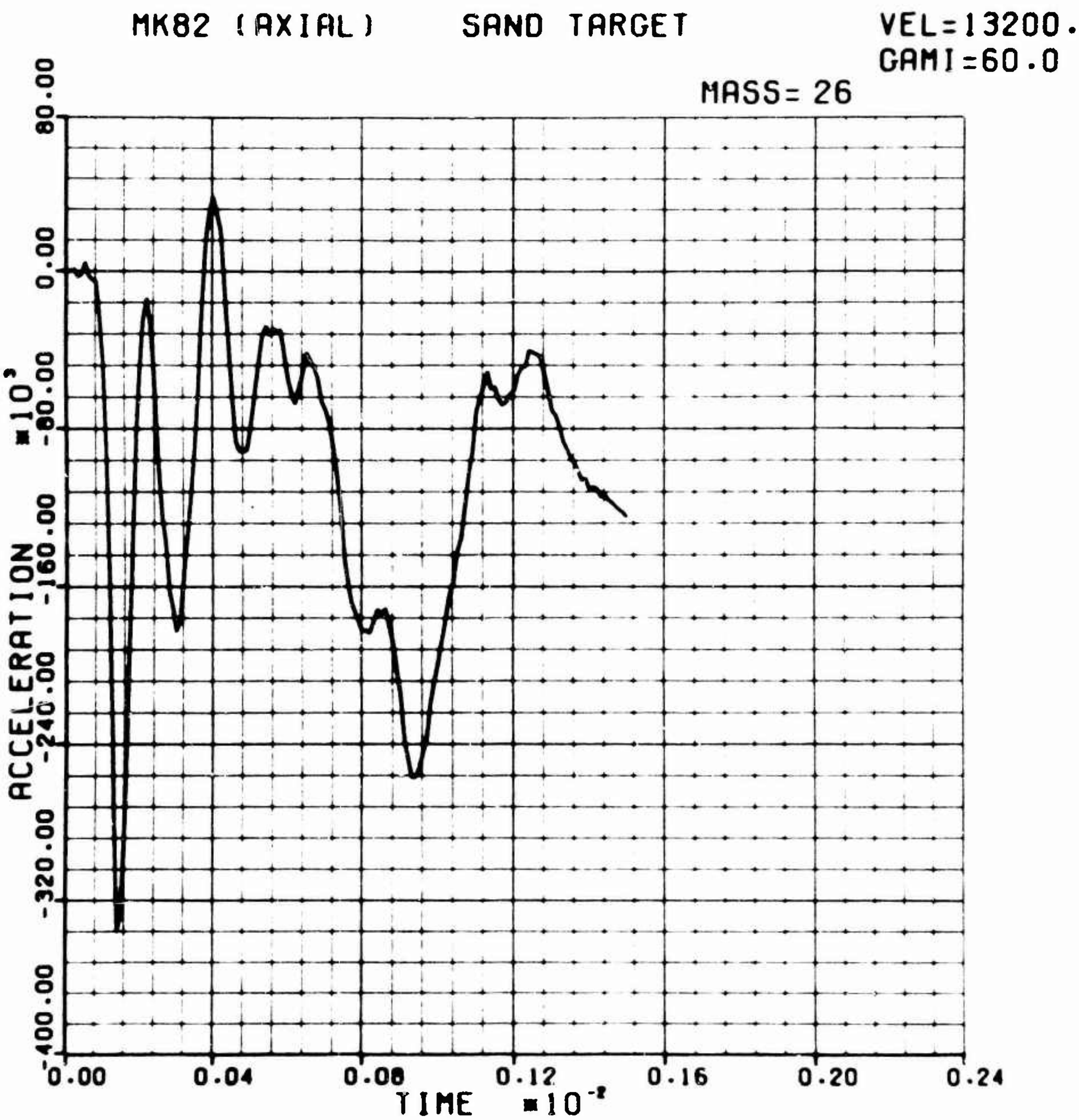
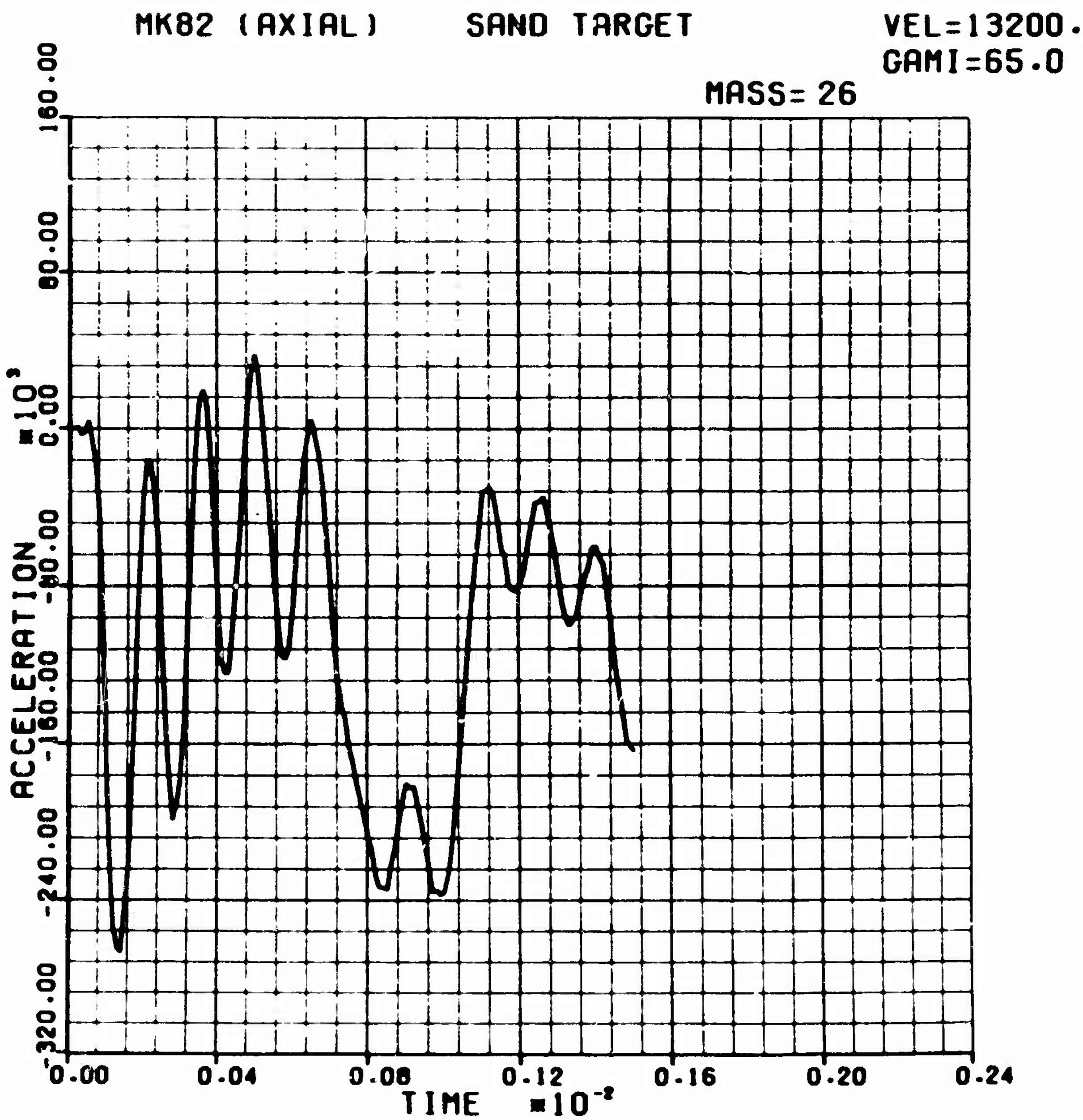
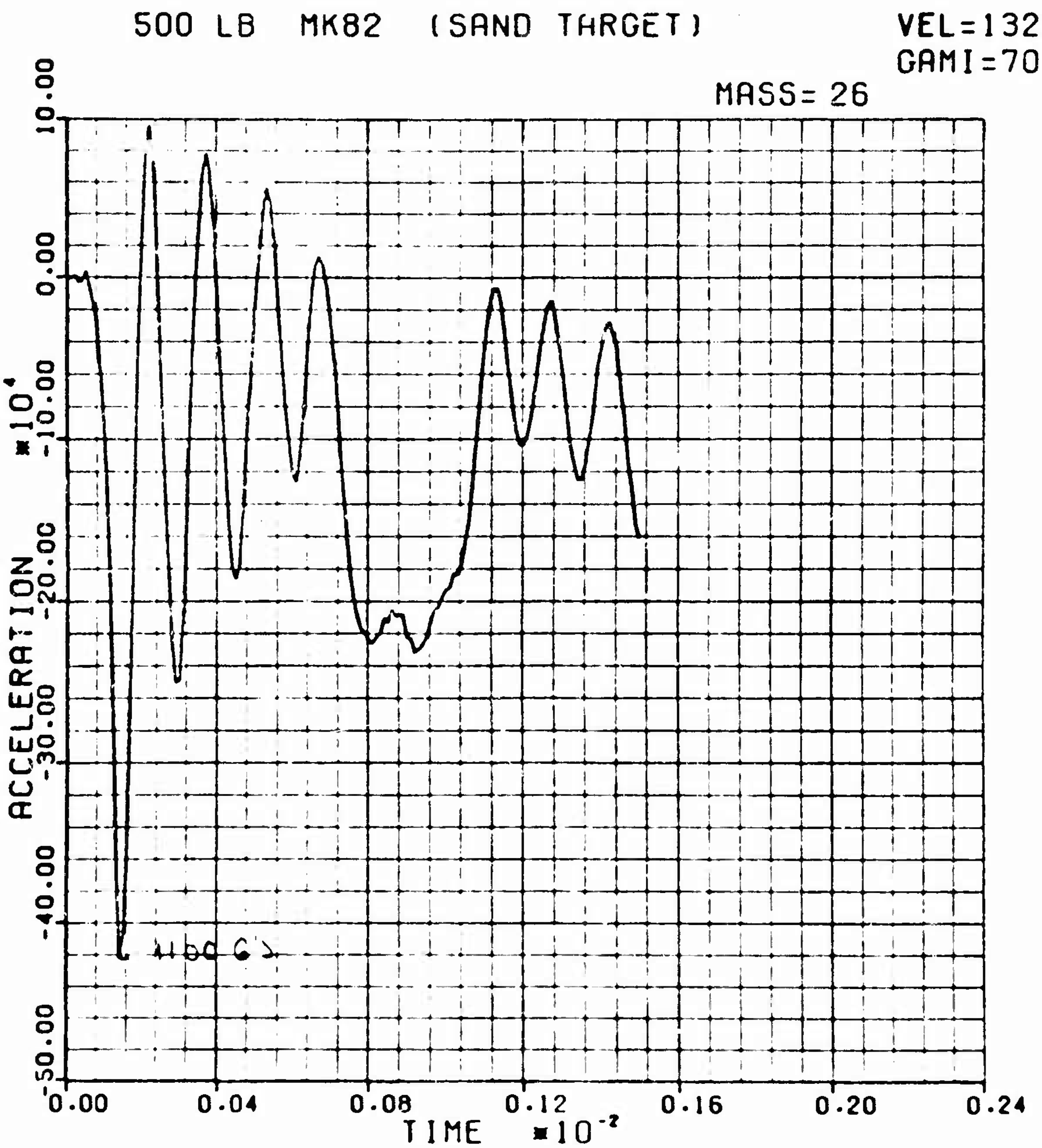
10.00
0.00
-10.00
-20.00
-30.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

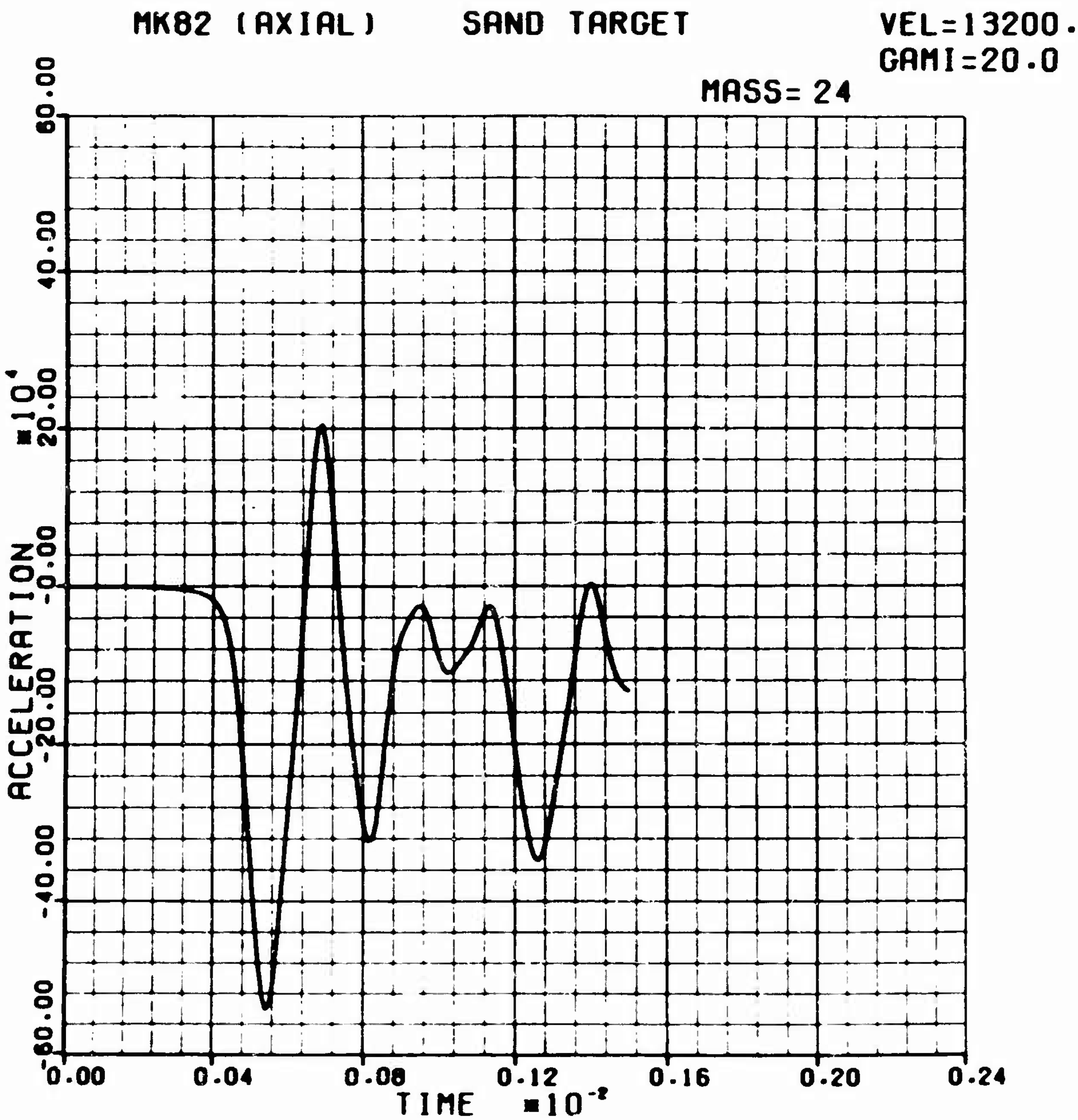

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 26
ACCELERATION *10^4
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

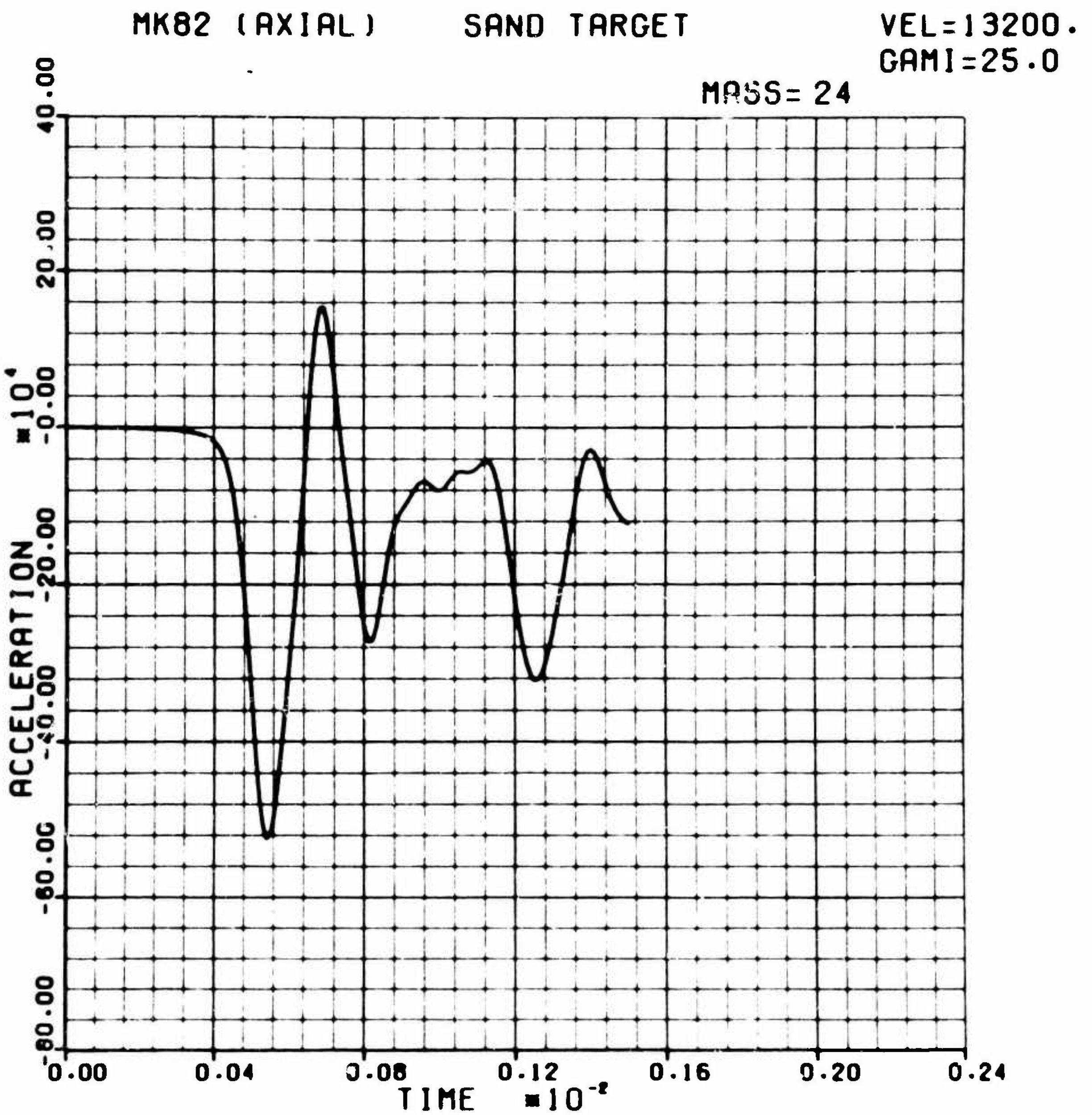


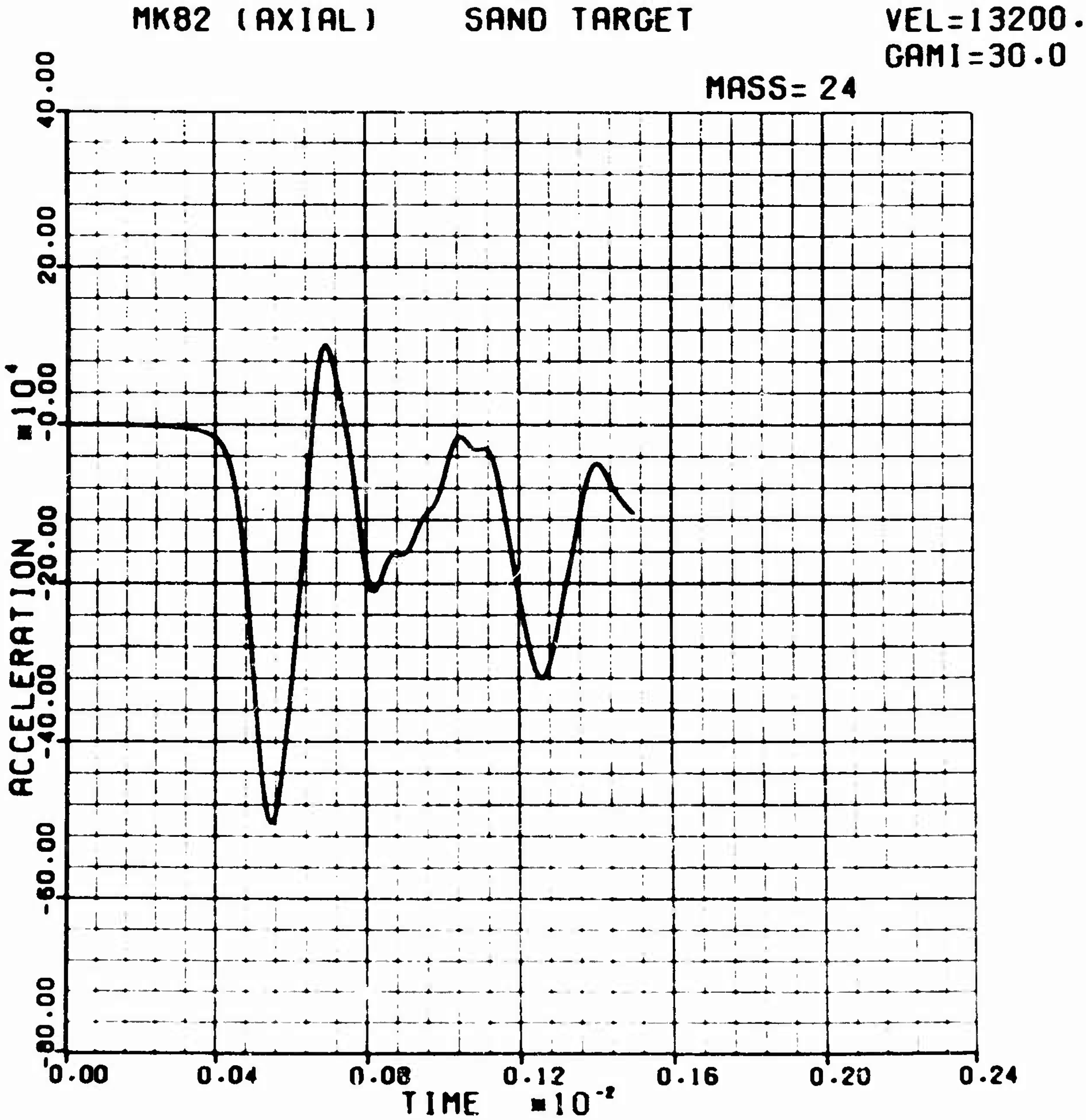
MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=60.0
MASS= 26
80.00
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
ACCELERATION ×10³
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

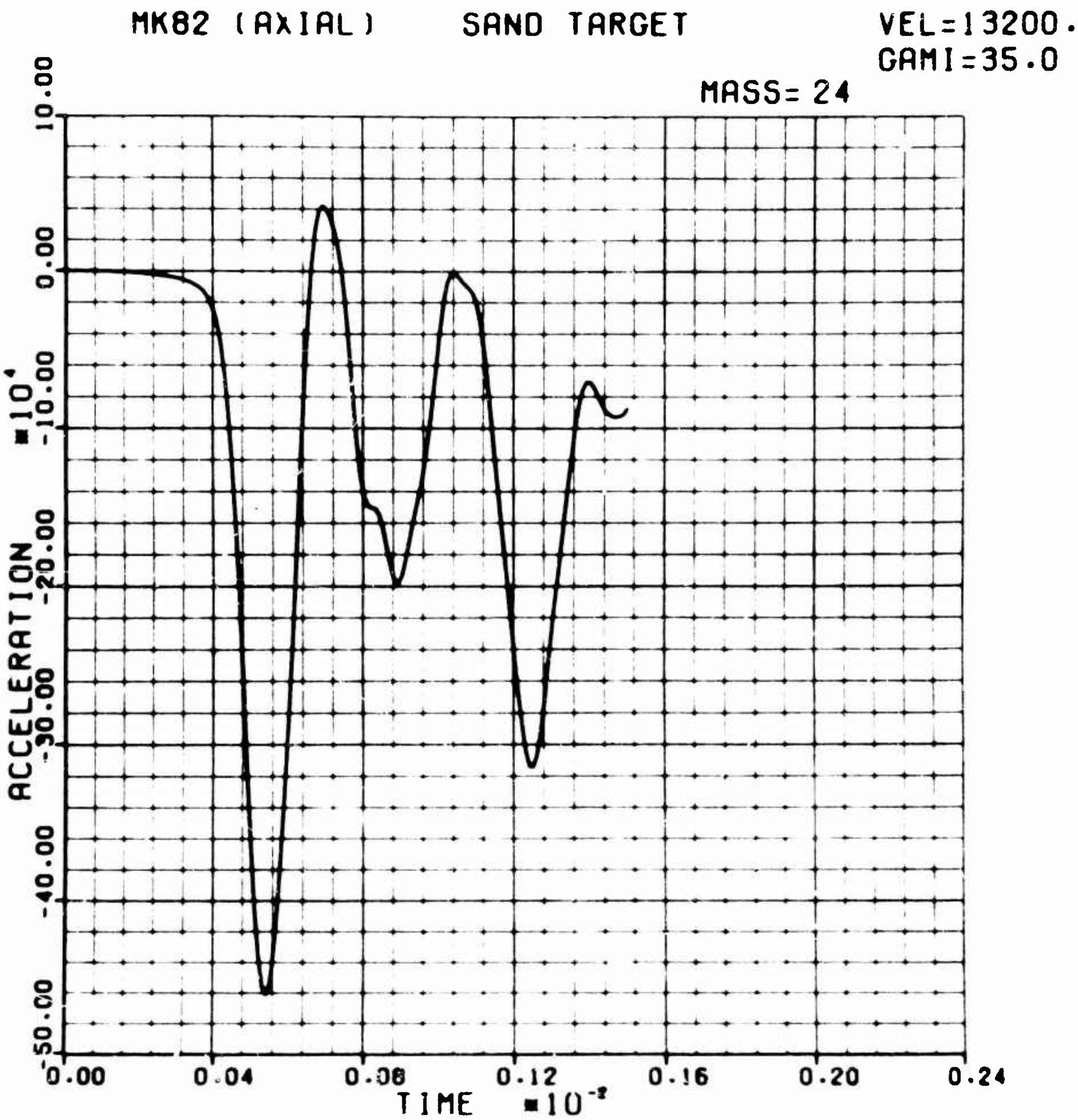

MK82 (AXIAL) SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 26
ACCELERATION *10^3
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

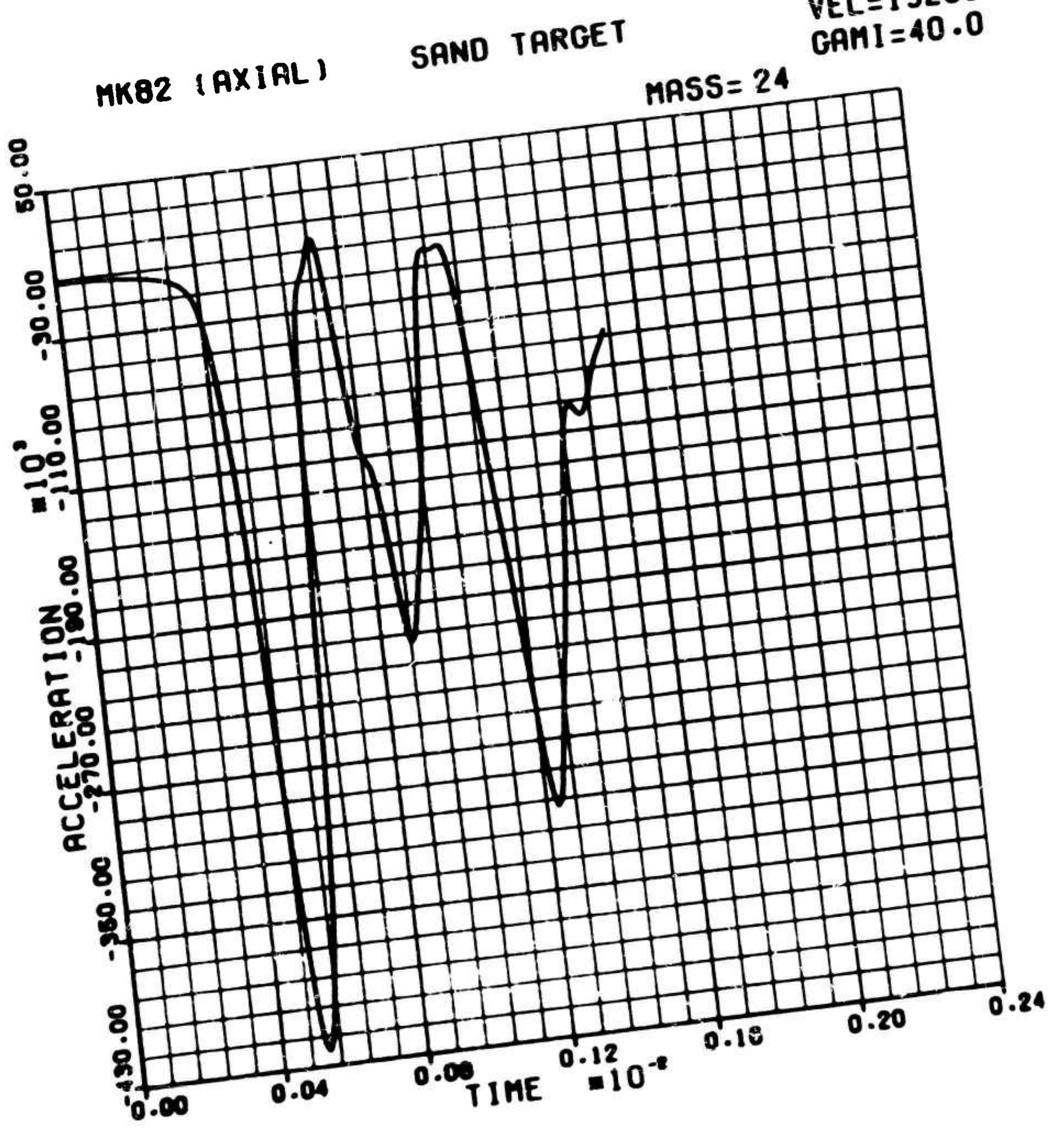

500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 26
ACCELERATION ×10⁴
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

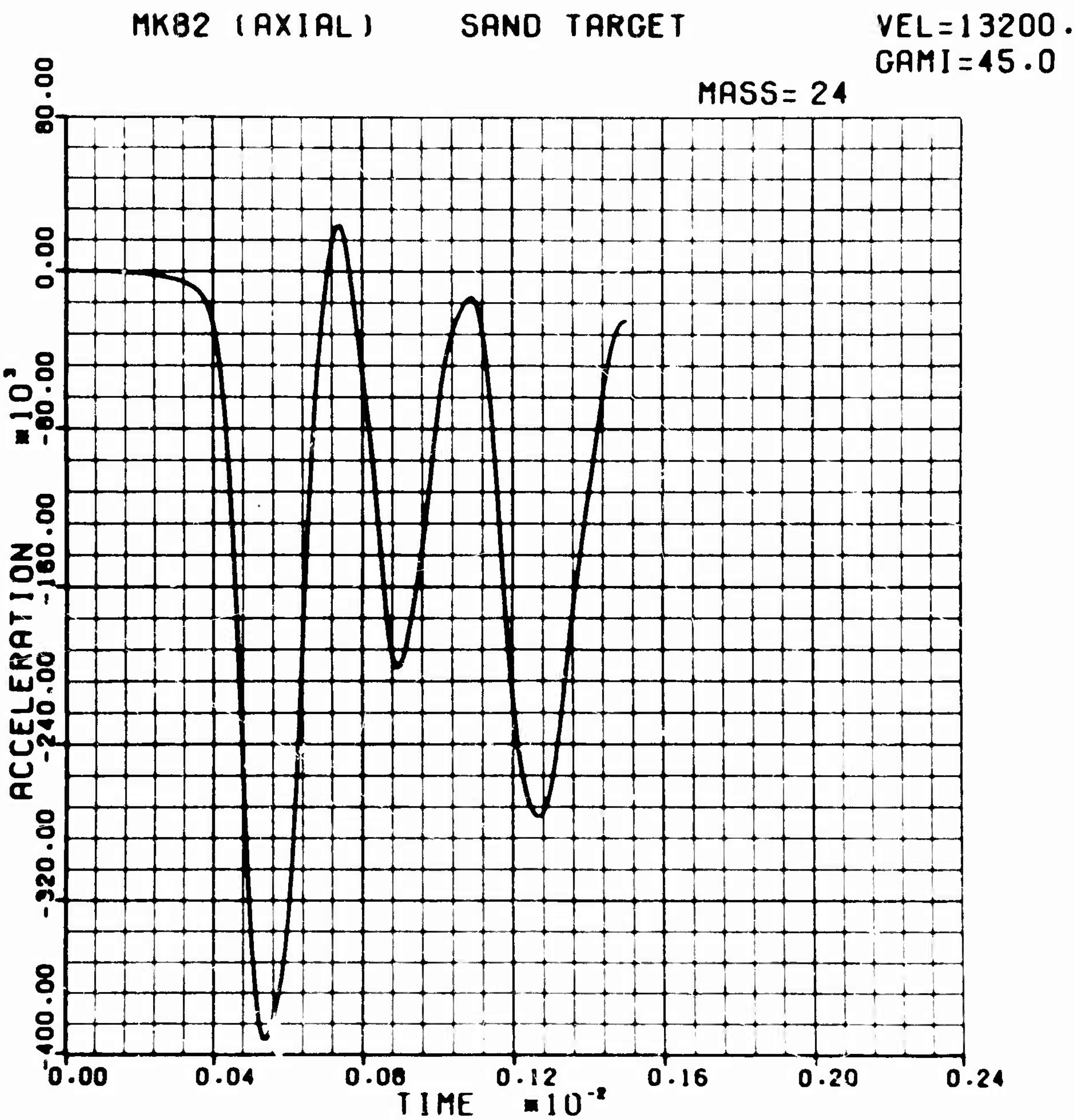

MK82 (AXIAL) SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 24
ACCELERATION *10^4
60.00
40.00
20.00
-0.00
-20.00
-40.00
-60.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

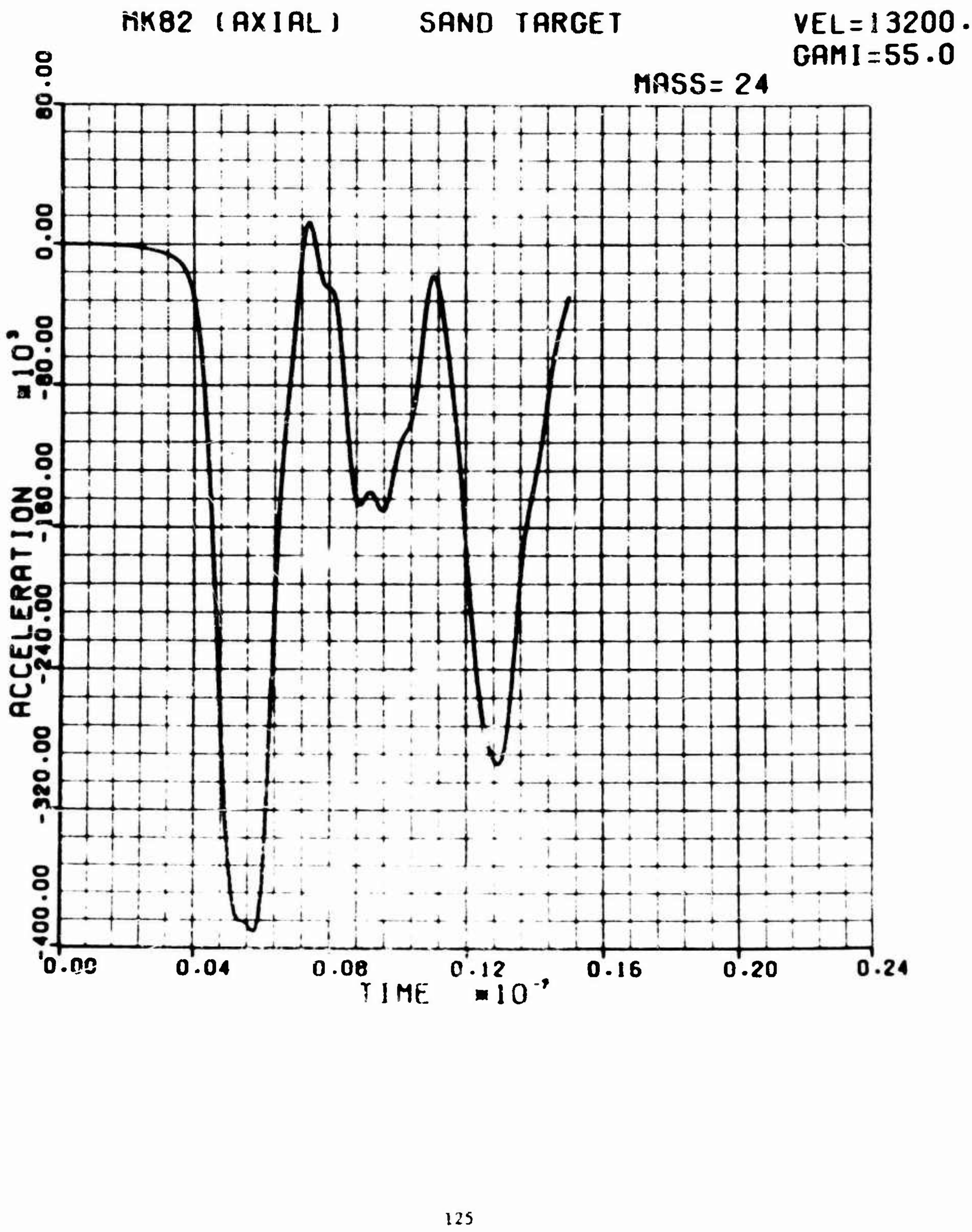

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=25.0
MASS= 24
ACCELERATION *10^4
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
TIME *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24

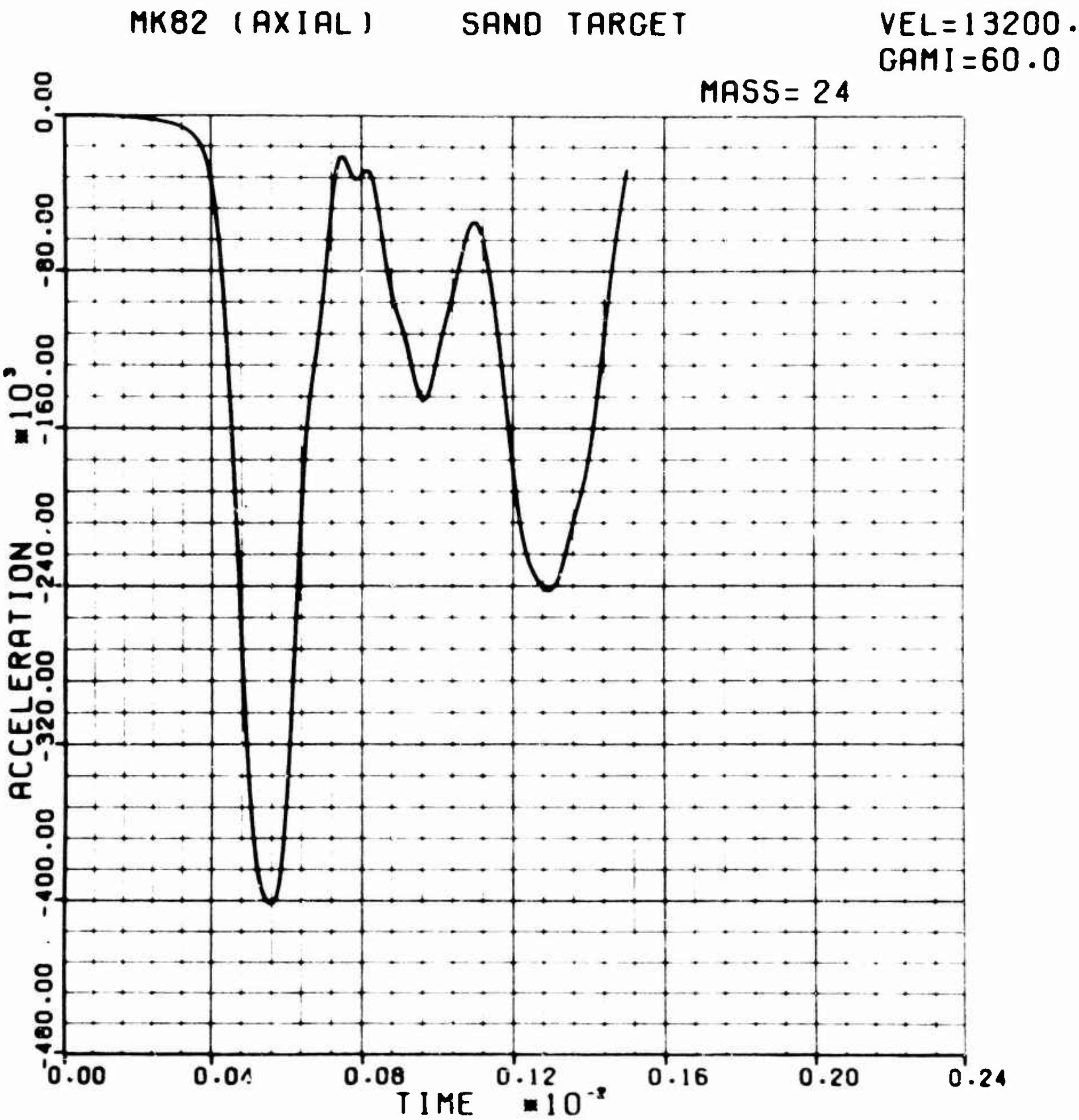

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=30.0
MASS= 24
ACCELERATION *10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

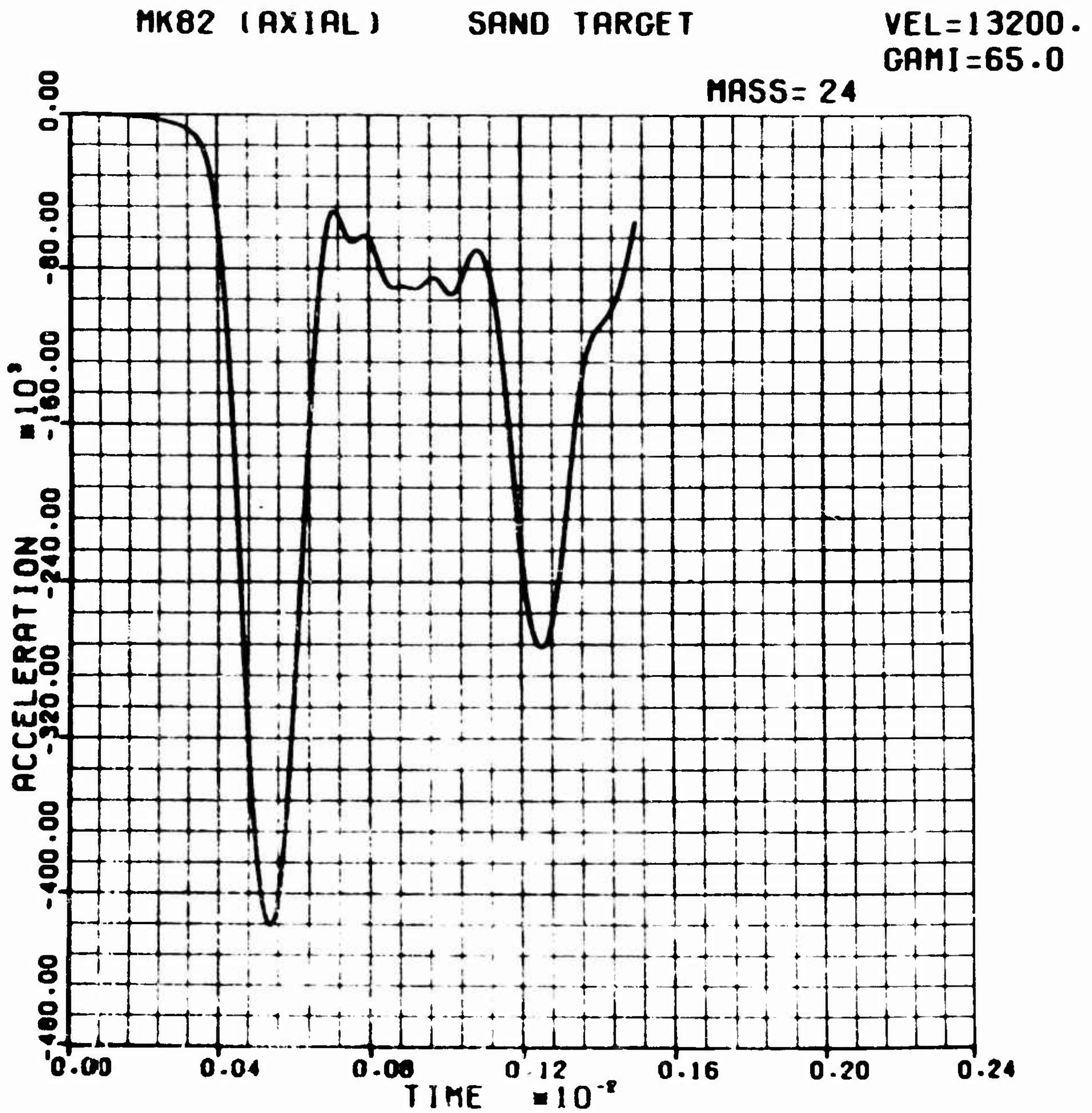

MK82 (AXIAL) SAND TARGET
VEL=13200.
GAMI=35.0
MASS= 24
ACCELERATION *10^4
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

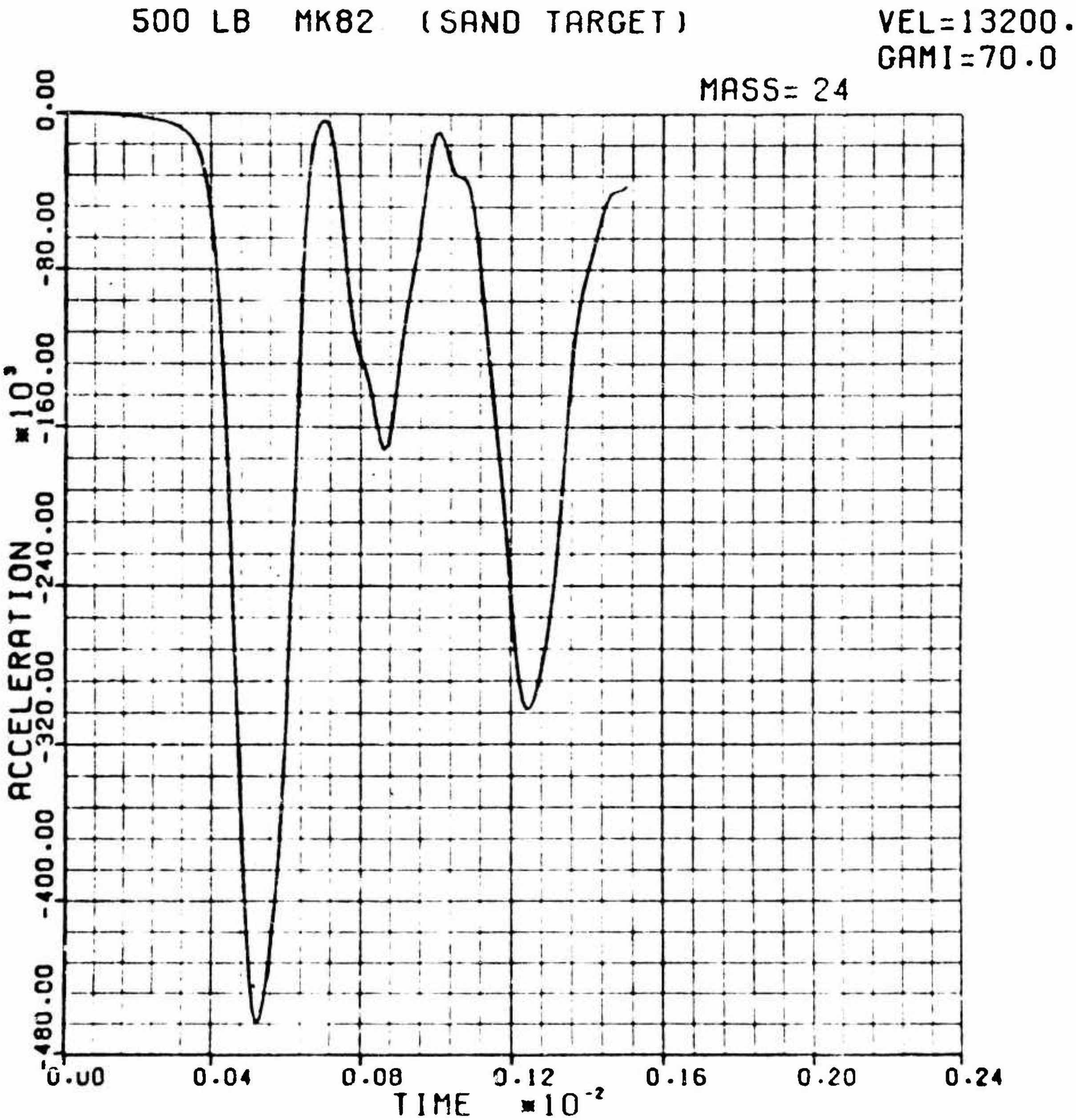

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=40.0
MASS= 24
ACCELERATION *10³
50.00
-30.00
-110.00
-190.00
-270.00
-350.00
-430.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24


MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=45.0
MASS= 24
ACCELERATION *10³
80.00
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

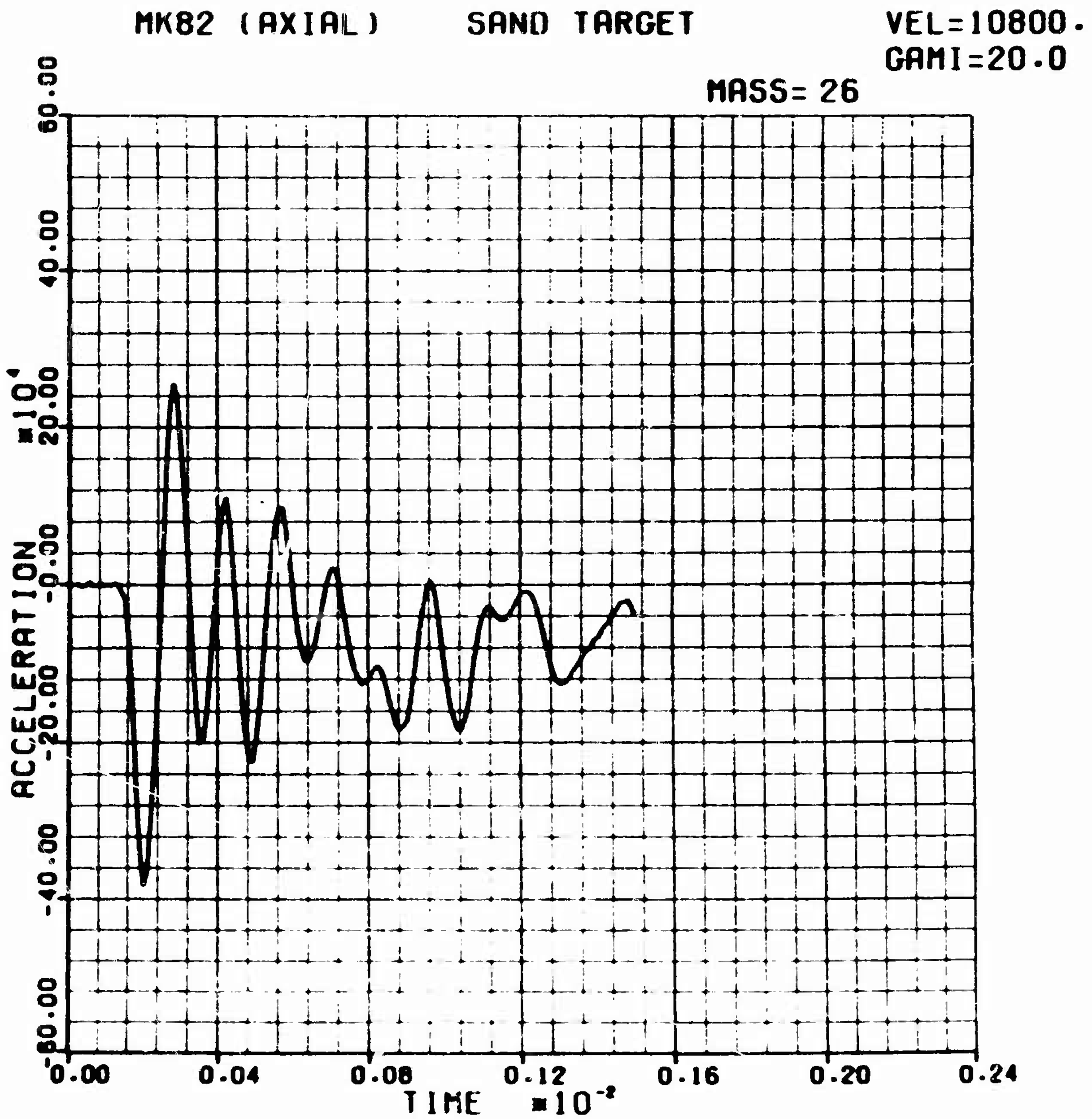

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 24
ACCELERATION *10³
80.00
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻¹


MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=60.0
MASS= 24
ACCELERATION *10^3
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
-480.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

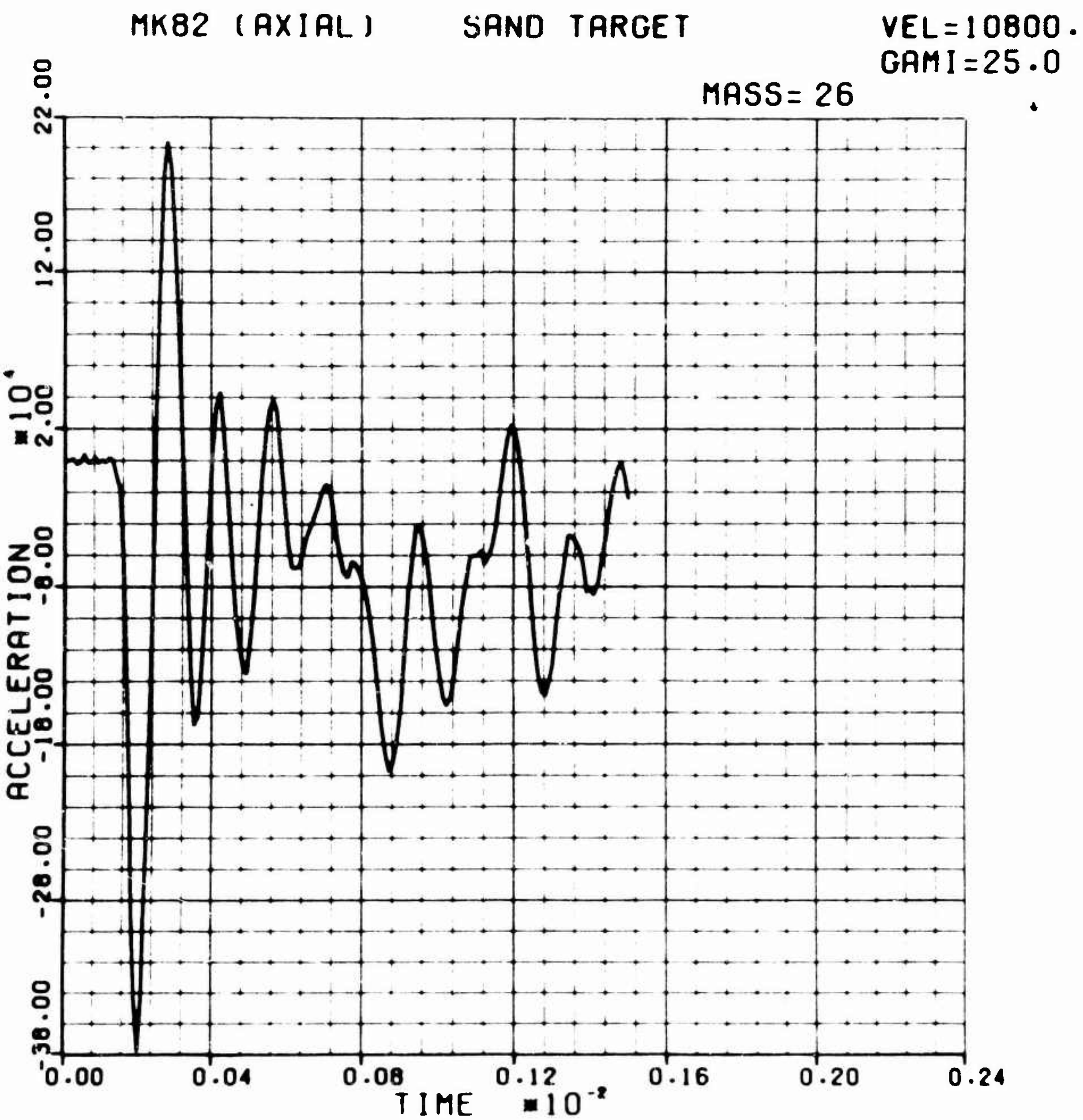

MK82 (AXIAL)
SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 24
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
-480.00
ACCELERATION $*10^{3}$
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$



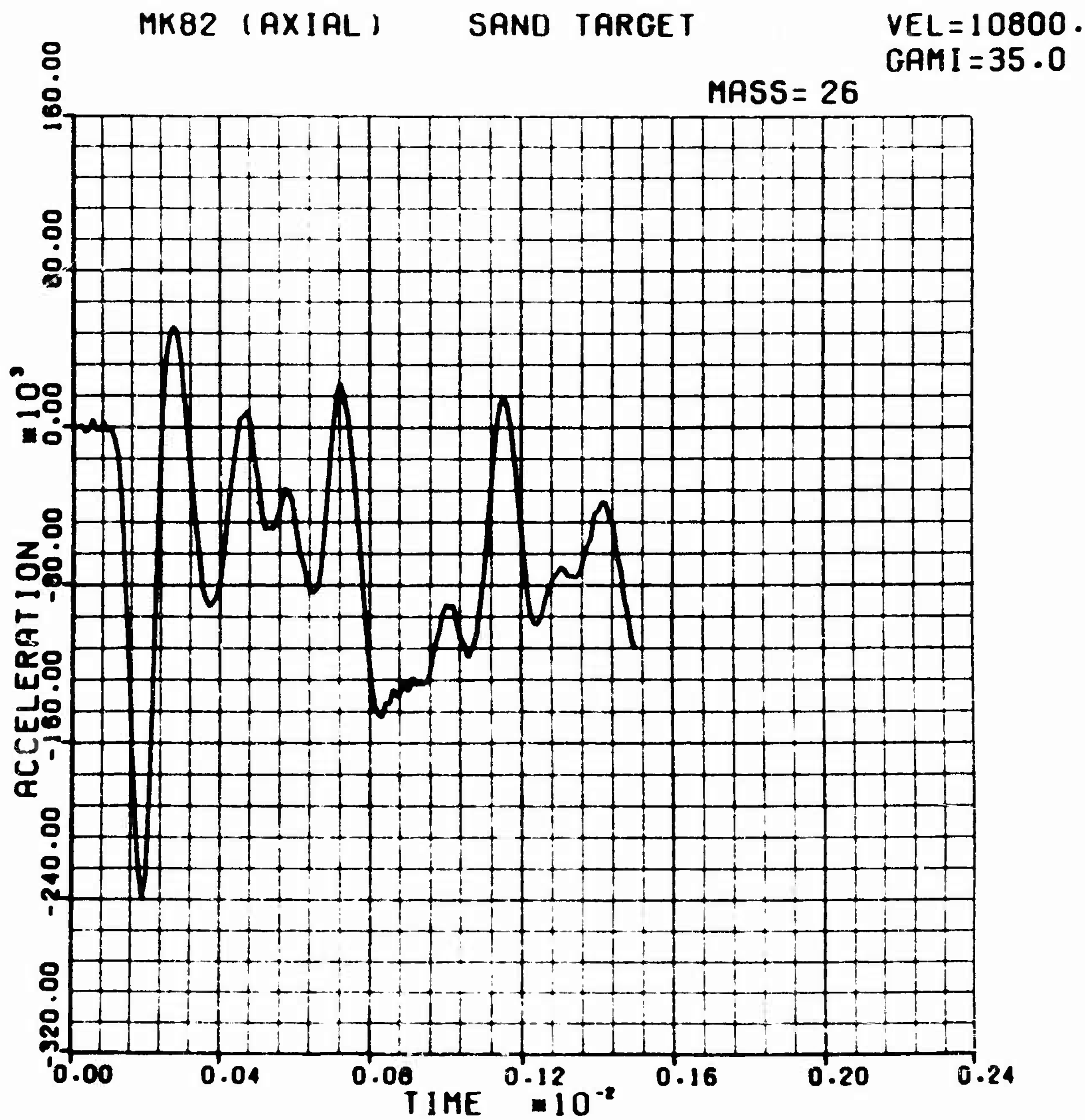
500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 24
ACCELERATION *10³
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
-480.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

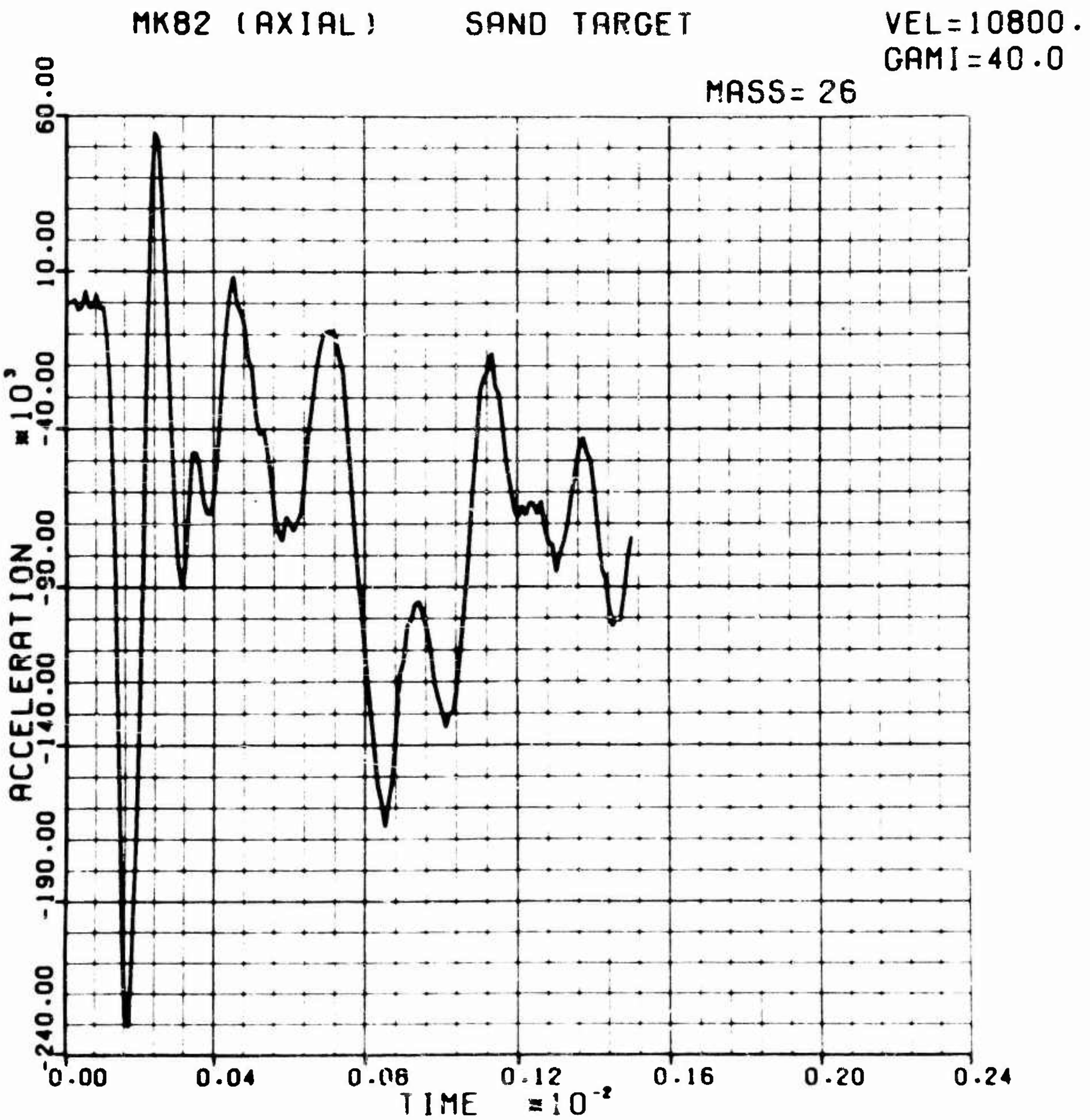


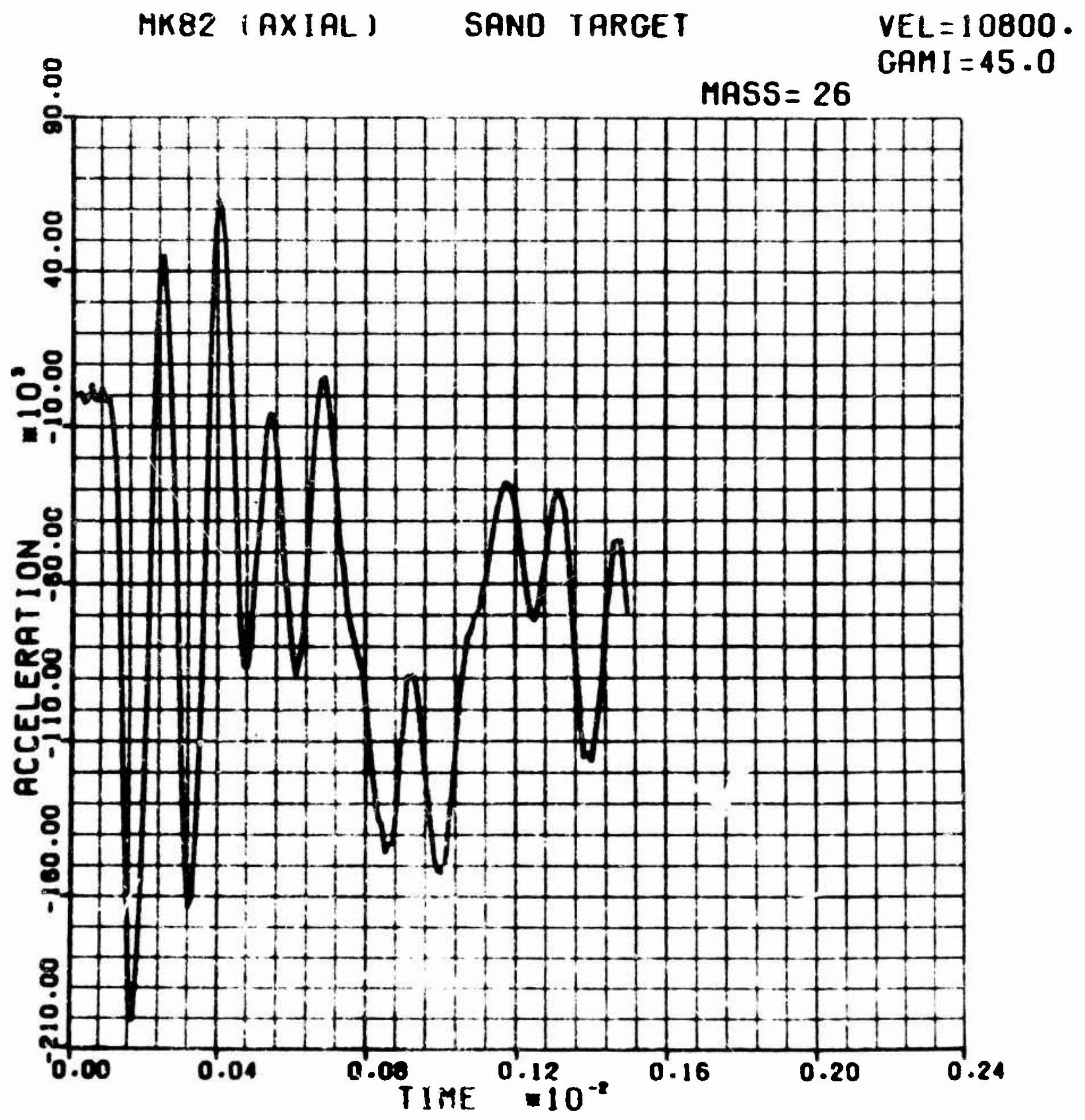
MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=20.0
MASS= 26
60.00
40.00
20.00
-0.00
-20.00
-40.00
-60.00
ACCELERATION ×10⁴
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

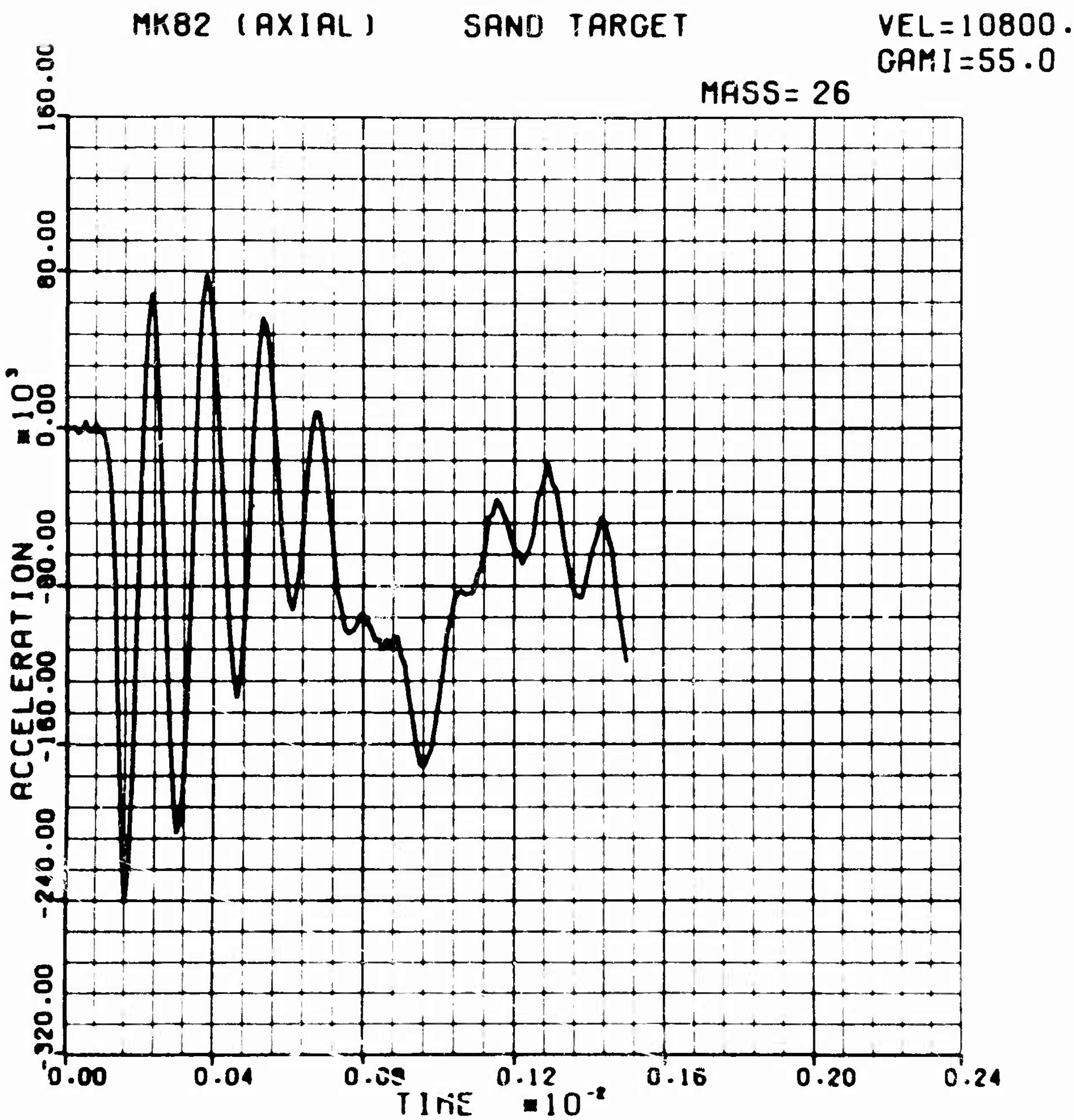


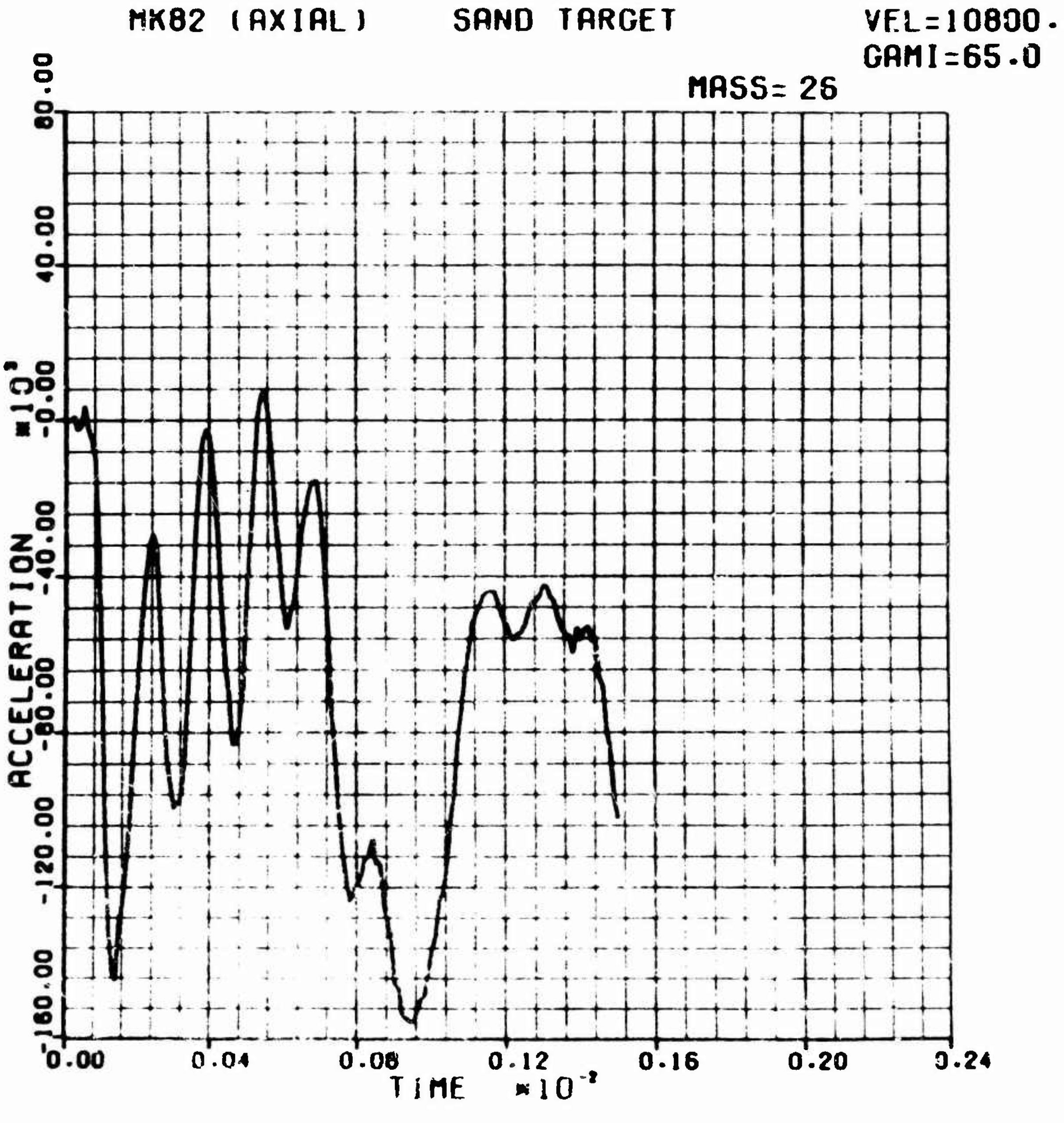
MK82 (AXIAL) SAND TARGET
VEL=10800.
GAMI=25.0
MASS= 26
ACCELERATION *10⁴
22.00
12.00
2.00
-8.00
-18.00
-28.00
-38.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24


MK82 (AXIAL)   SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 26
ACCELERATION *10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

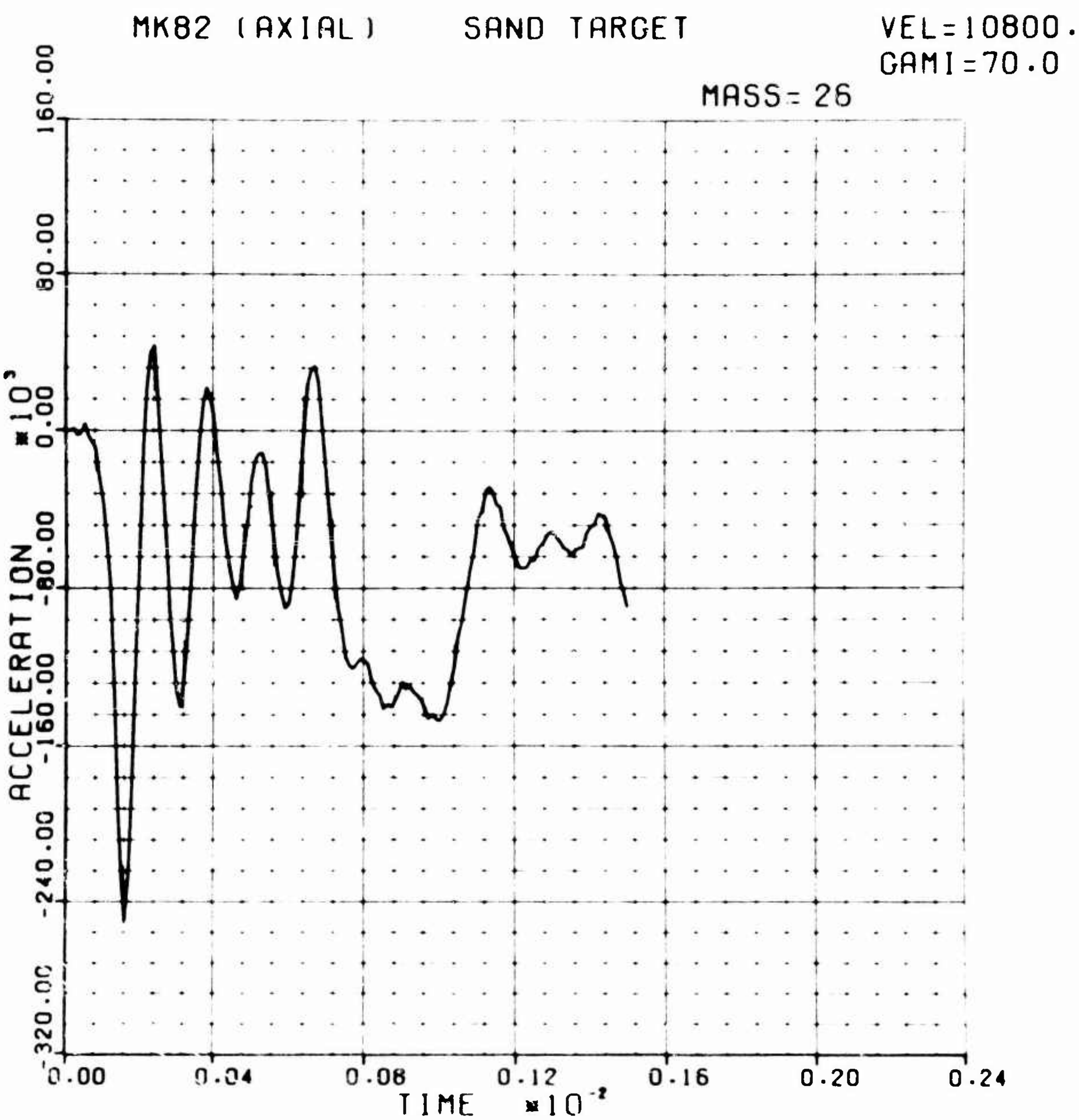

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=40.0
MASS= 26
ACCELERATION *10^3
60.00
10.00
-40.00
-90.00
-140.00
-190.00
-240.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

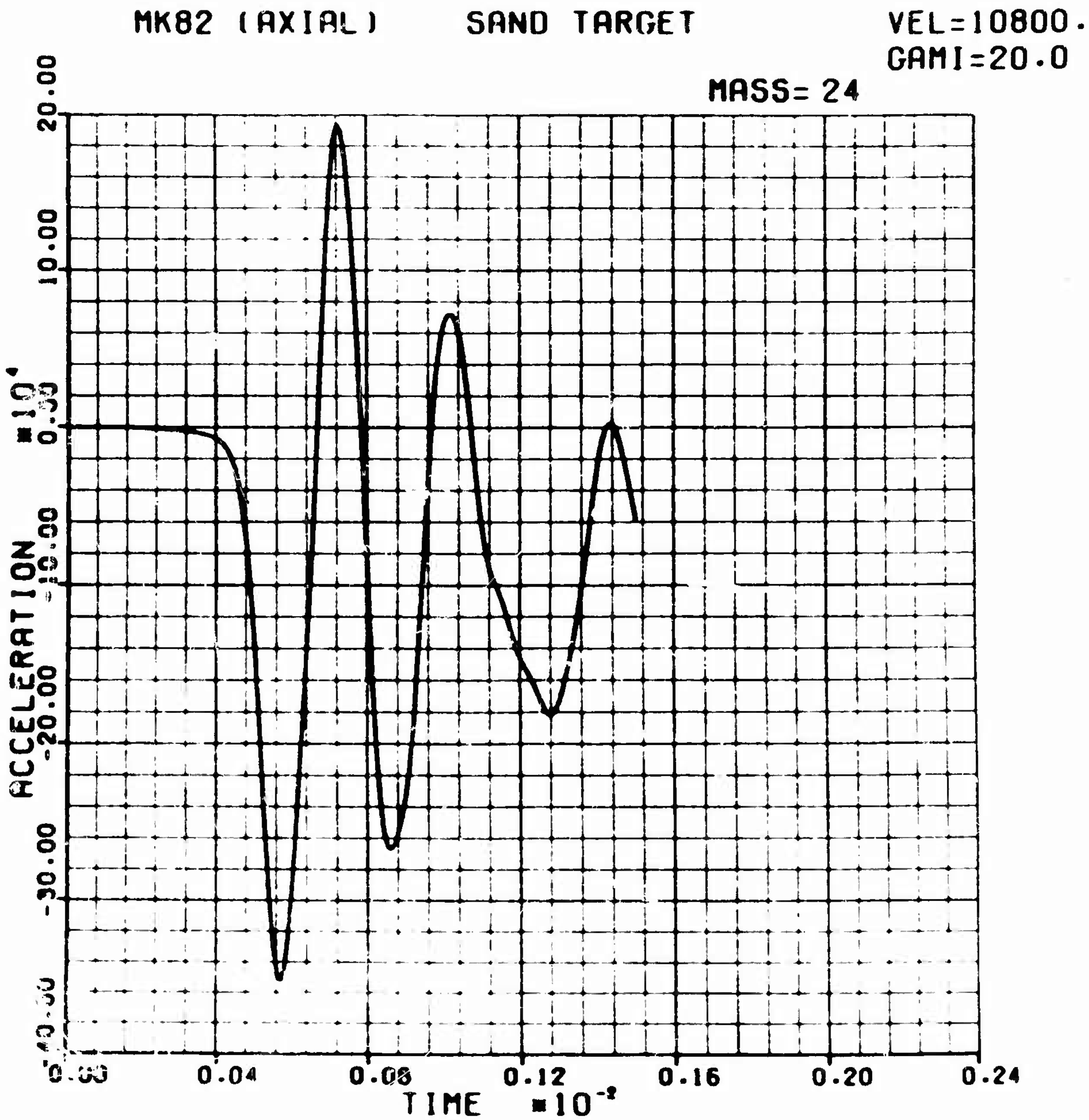

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 26
ACCELERATION $\times 10^{3}$
90.00
40.00
-10.00
-60.00
-110.00
-160.00
-210.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $\times 10^{-2}$

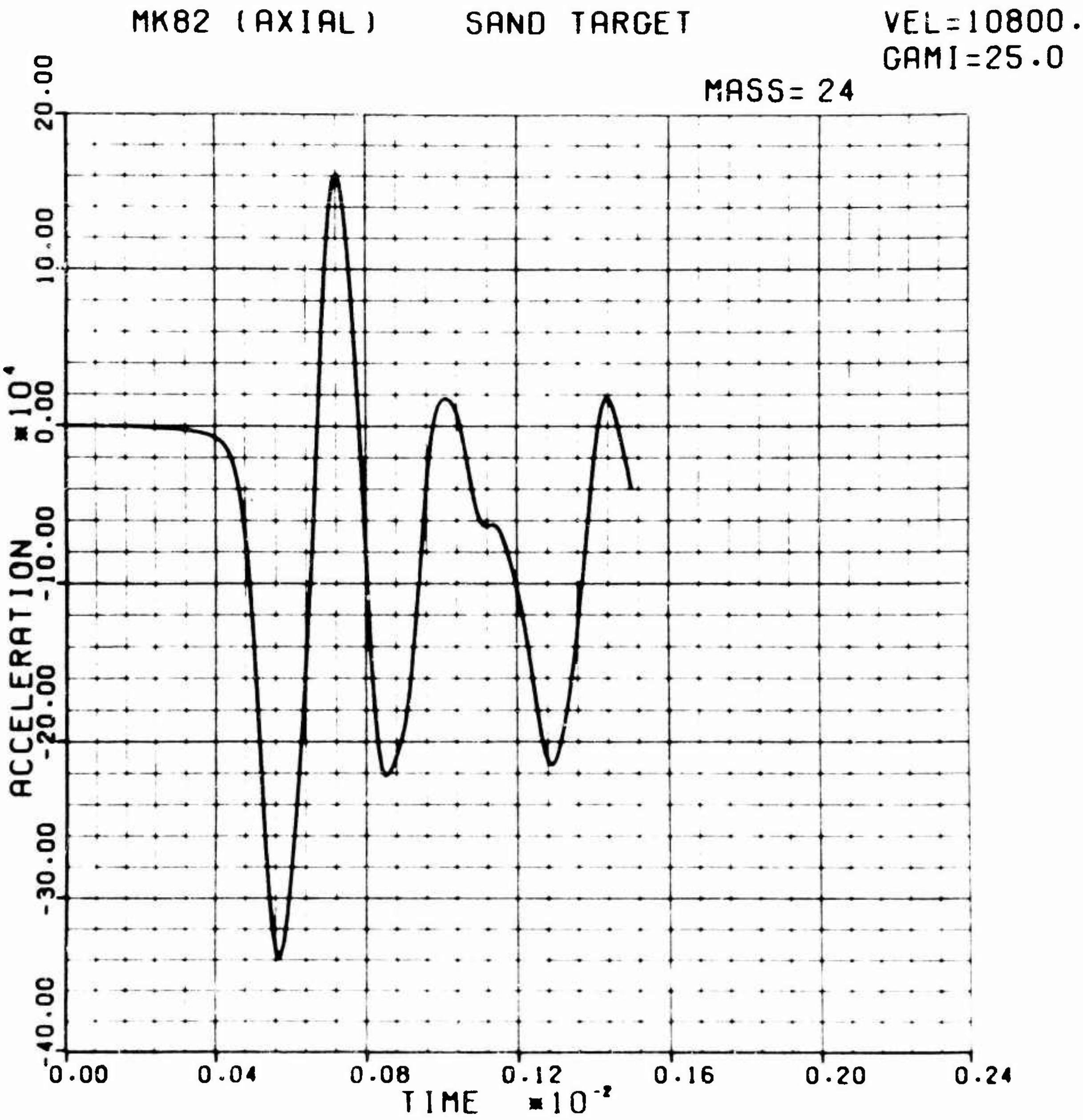

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=55.0
MASS= 26
ACCELERATION *10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

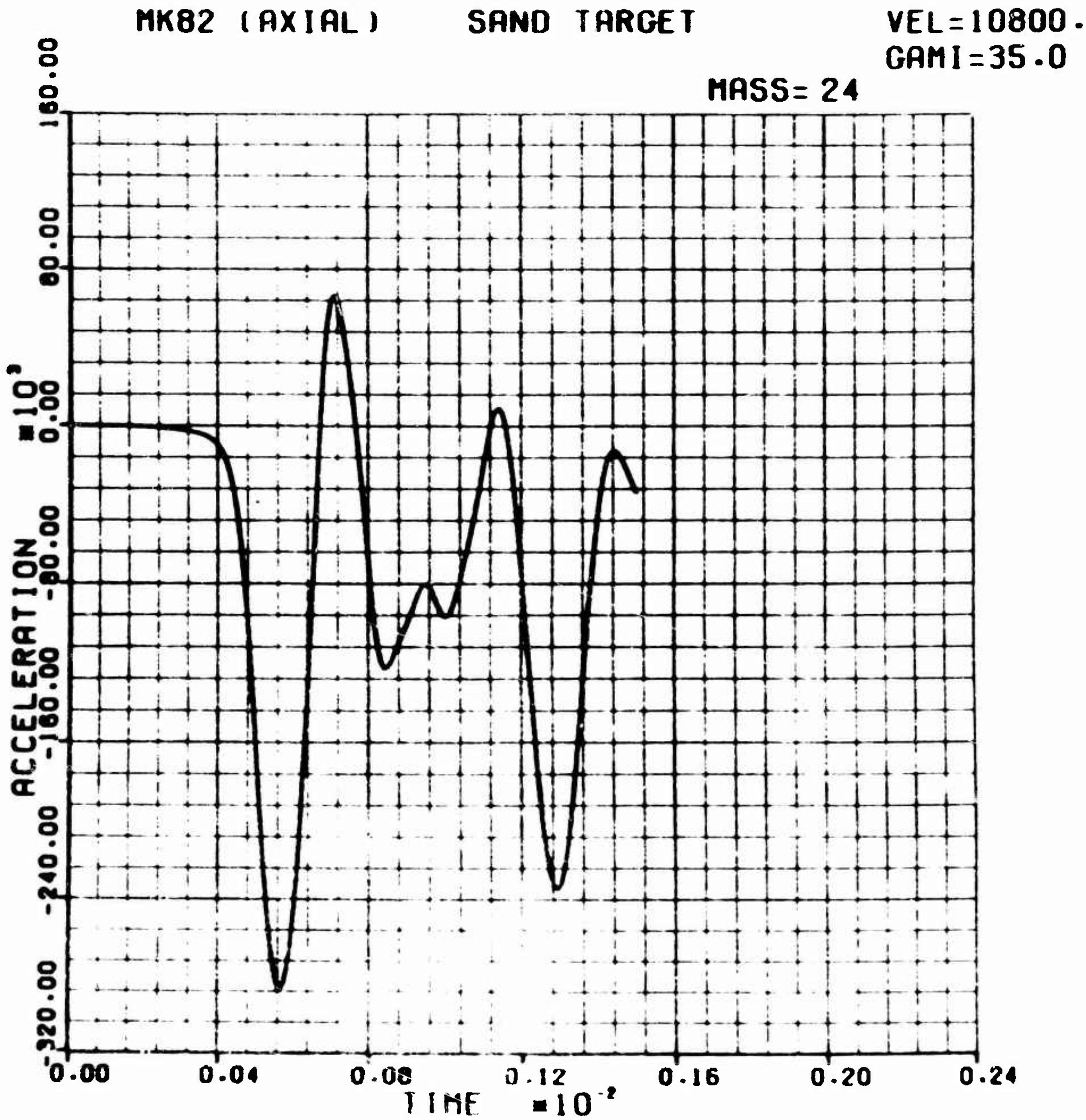


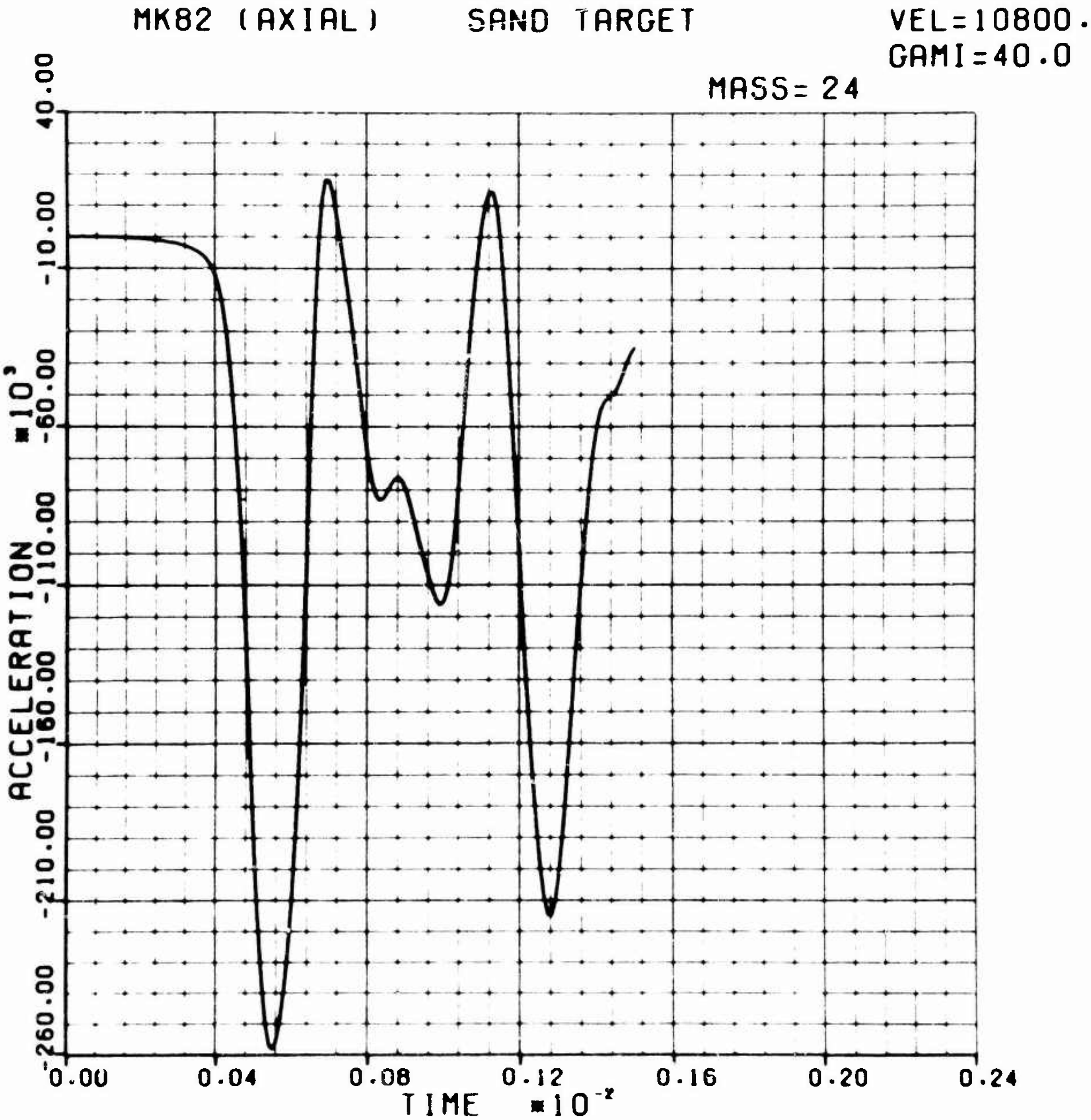
MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 26
ACCELERATION *10³
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

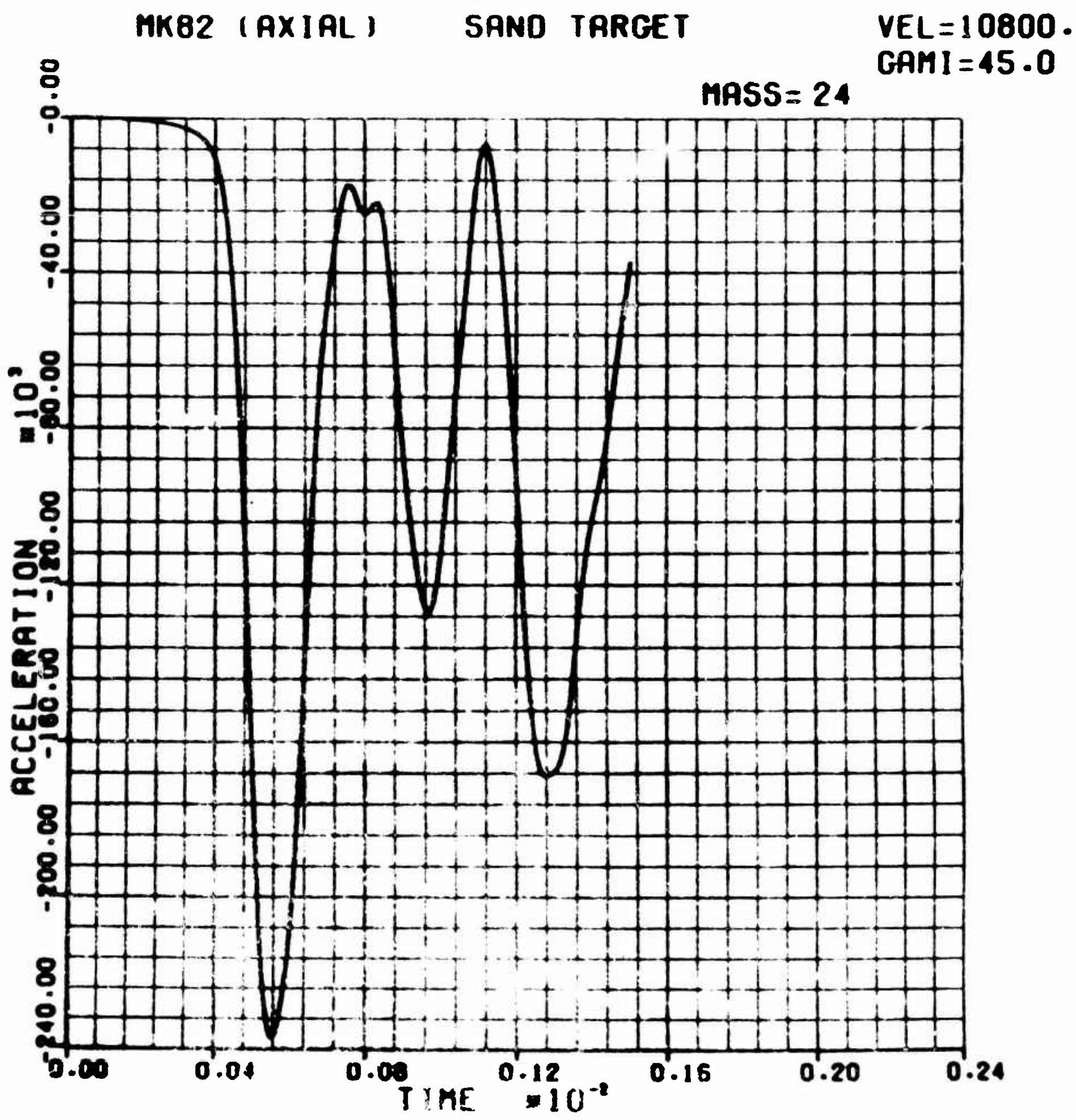

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=70.0
MASS= 26
ACCELERATION ✱10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ✱10⁻²

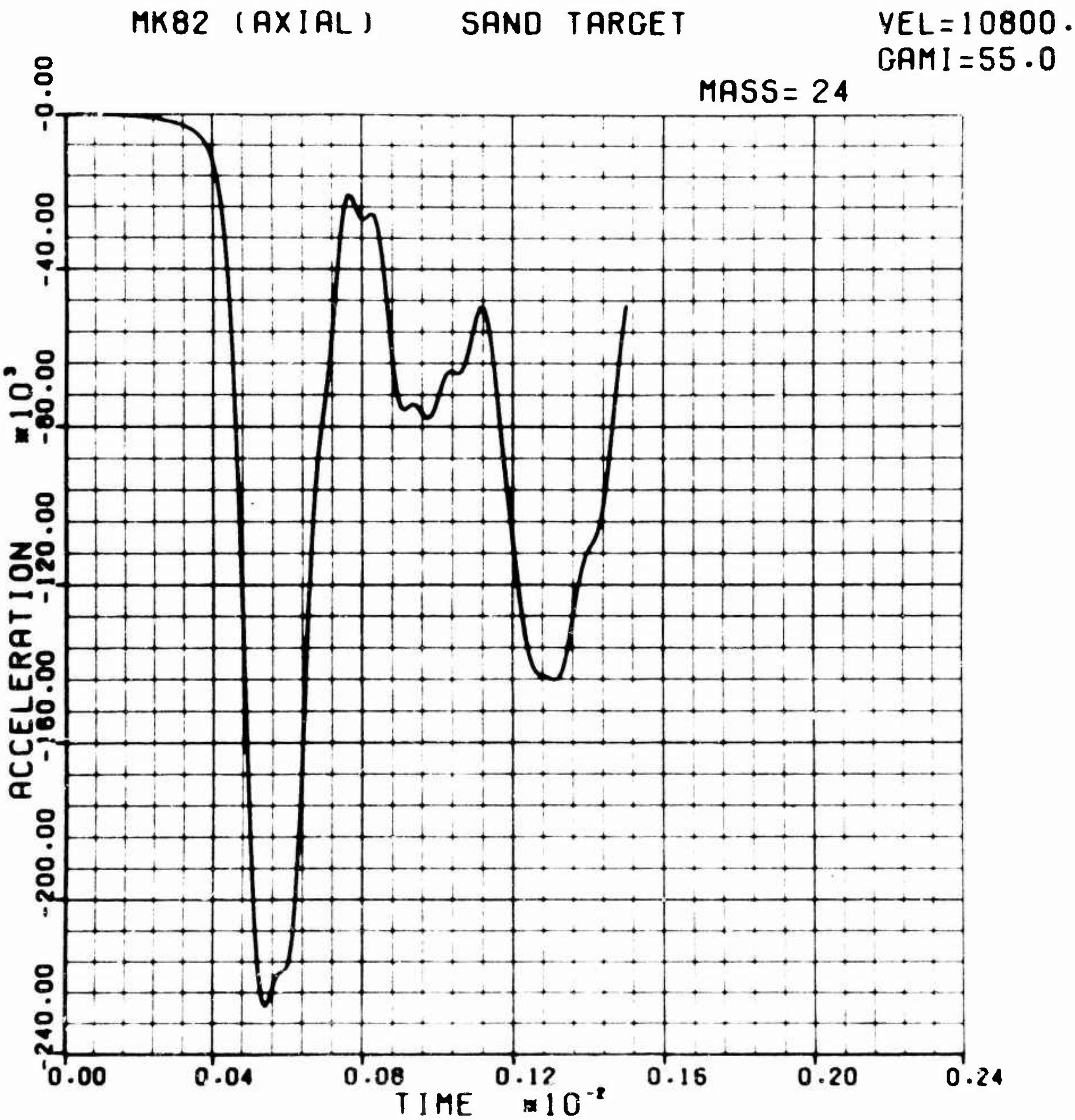

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=20.0
MASS= 24
ACCELERATION *10^4
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2


MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=25.0
MASS= 24
ACCELERATION *10⁴
TIME *10⁻²
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24

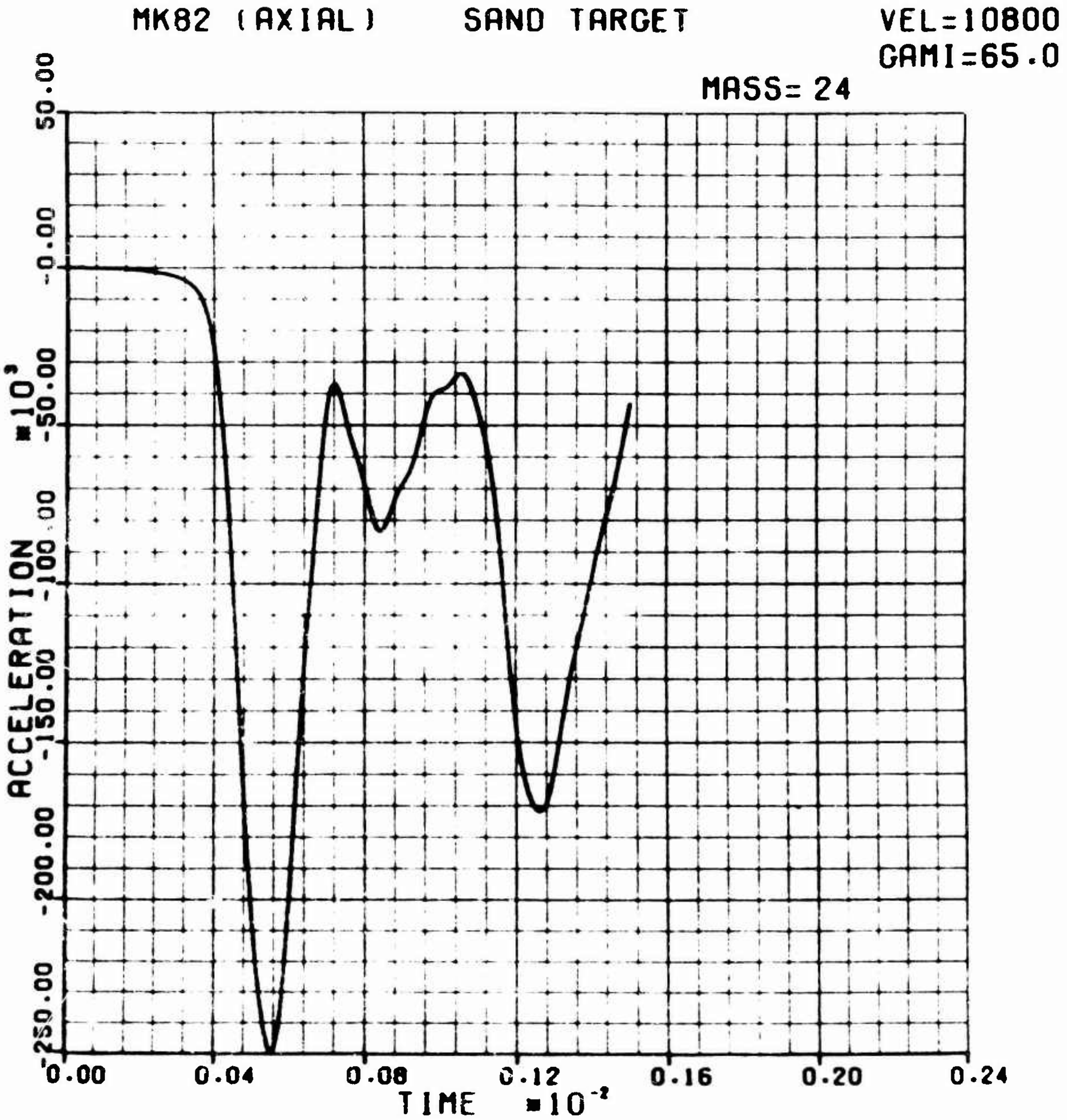

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 24
ACCELERATION *10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

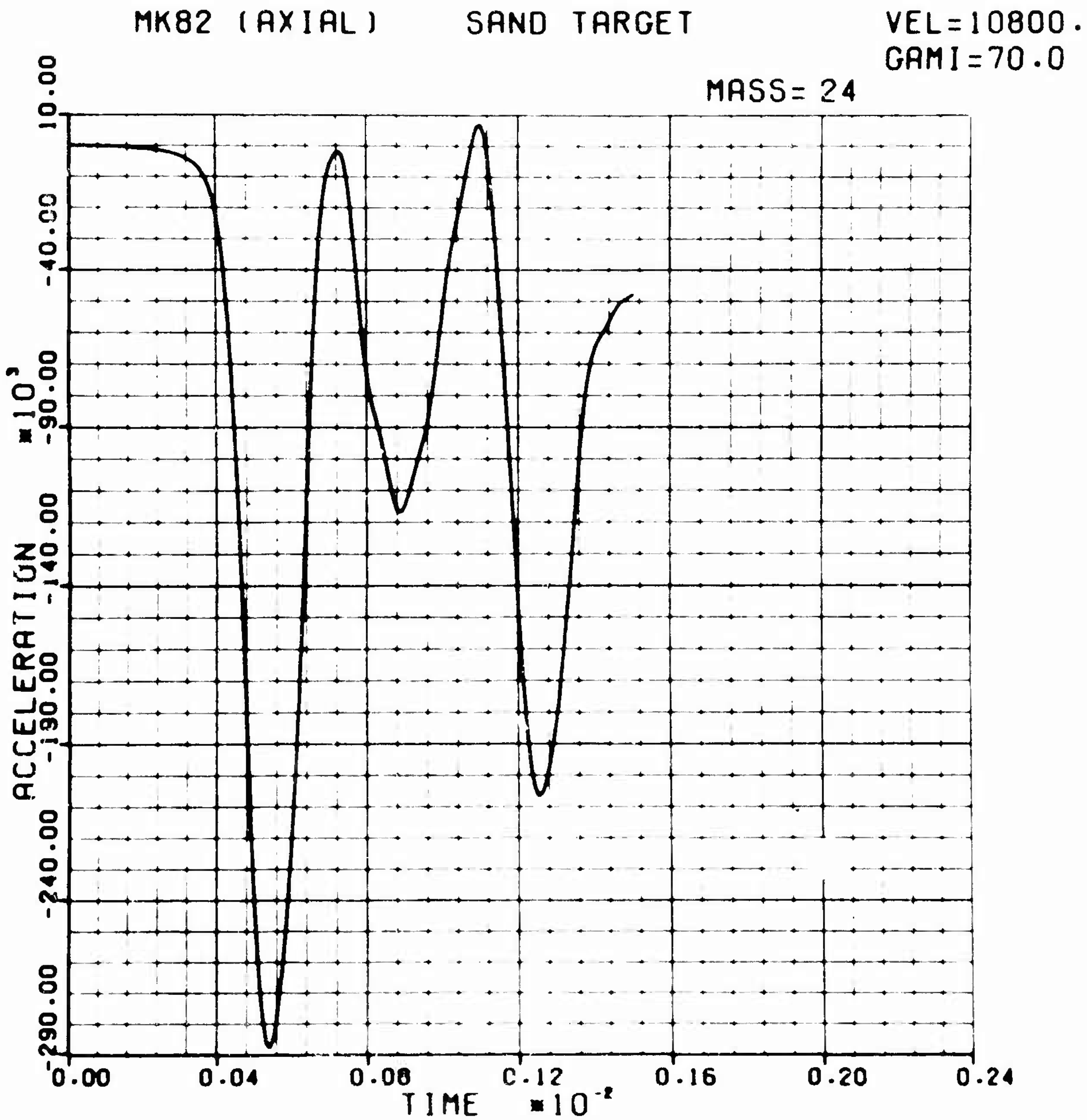

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=40.0
MASS= 24
ACCELERATION *10³
40.00
-10.00
-60.00
-110.00
-160.00
-210.00
-260.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

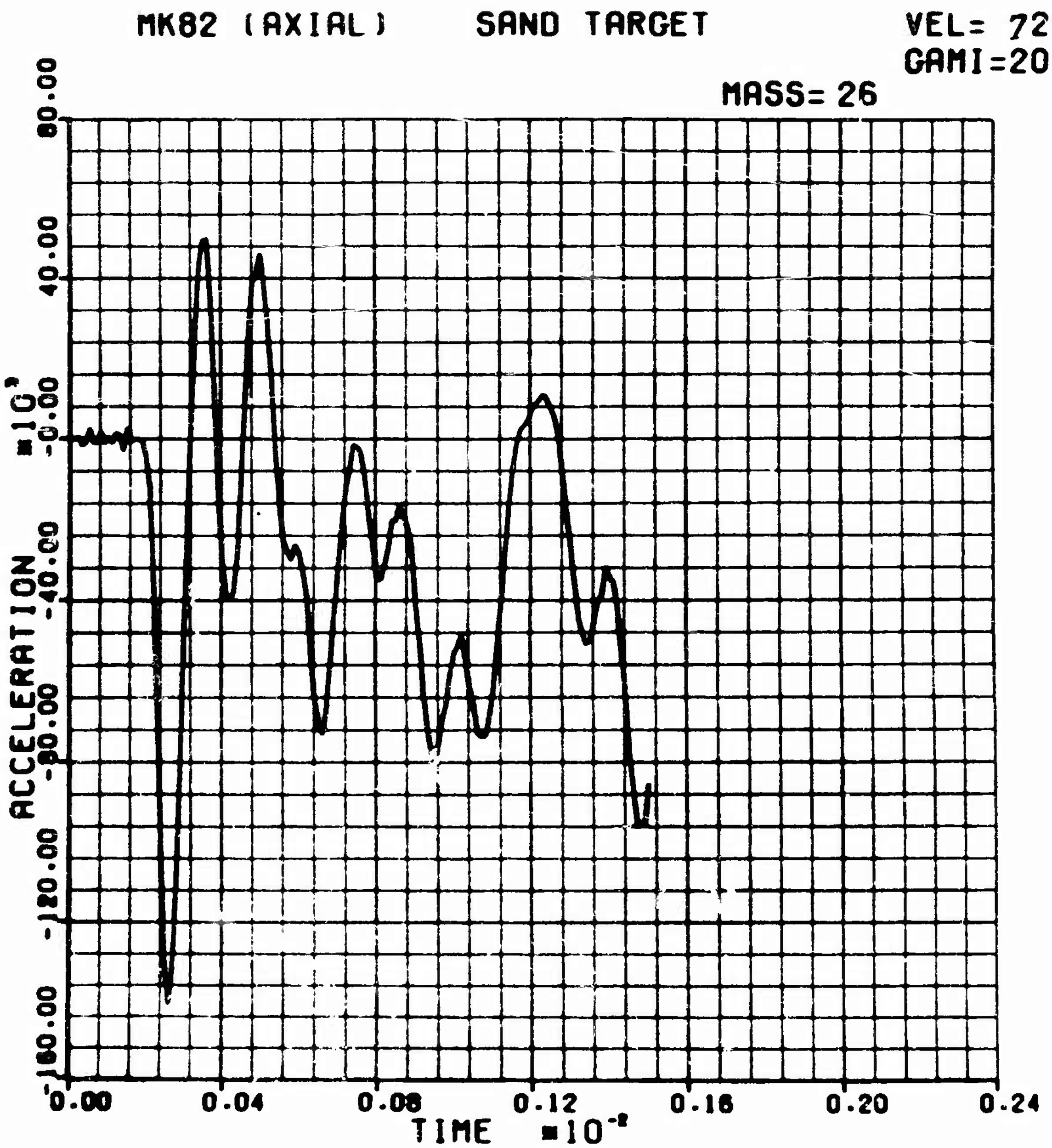

MK82 (AXIAL) SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 24
ACCELERATION *10^3
-0.00
-40.00
-80.00
-120.00
-160.00
-200.00
-240.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2



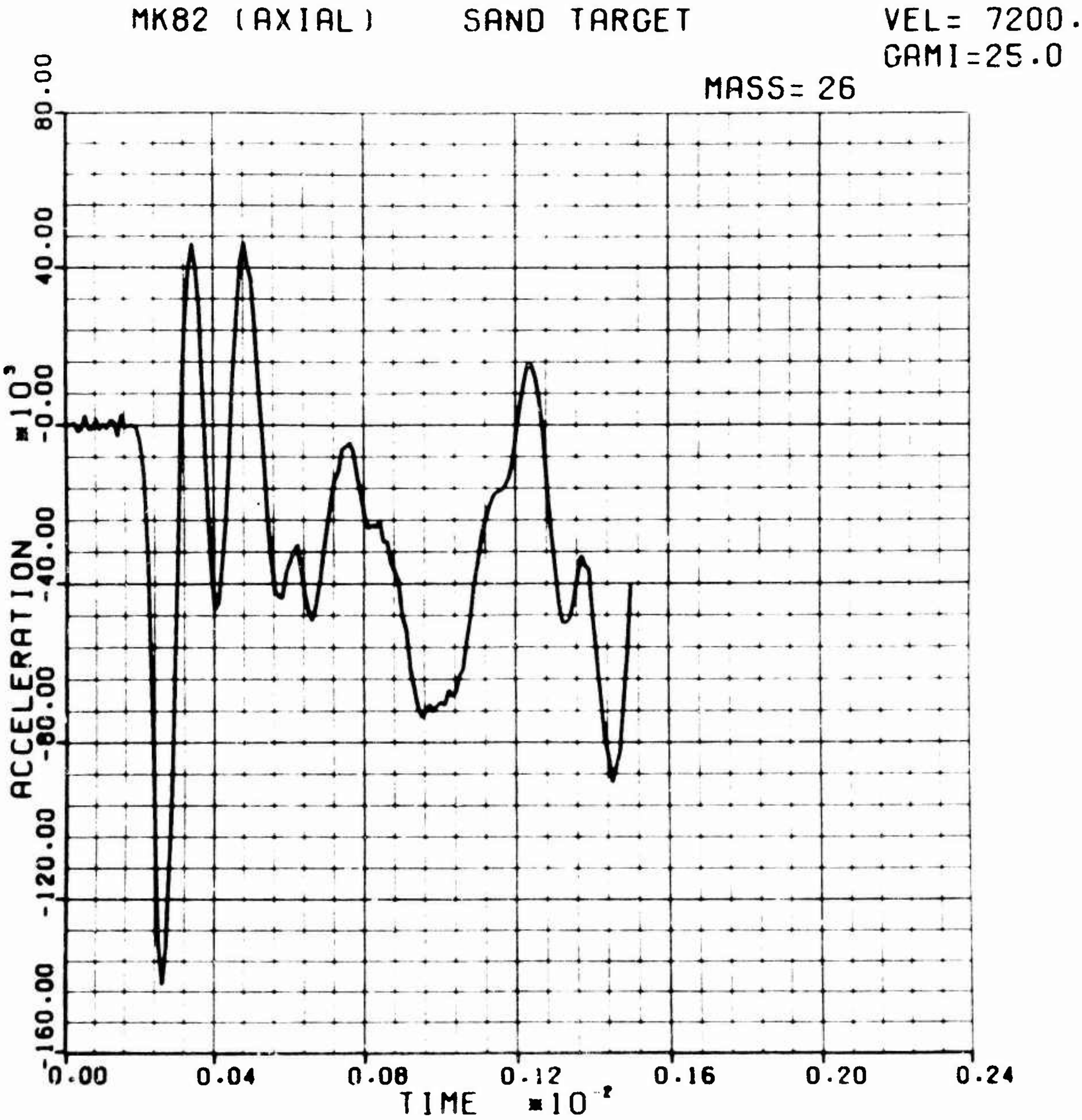
MK82 (AXIAL) SAND TARGET
VEL=10800.
GAMI=55.0
MASS= 24
ACCELERATION ×10³
-0.00
-40.00
-80.00
-120.00
-160.00
-200.00
-240.00
TIME ×10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

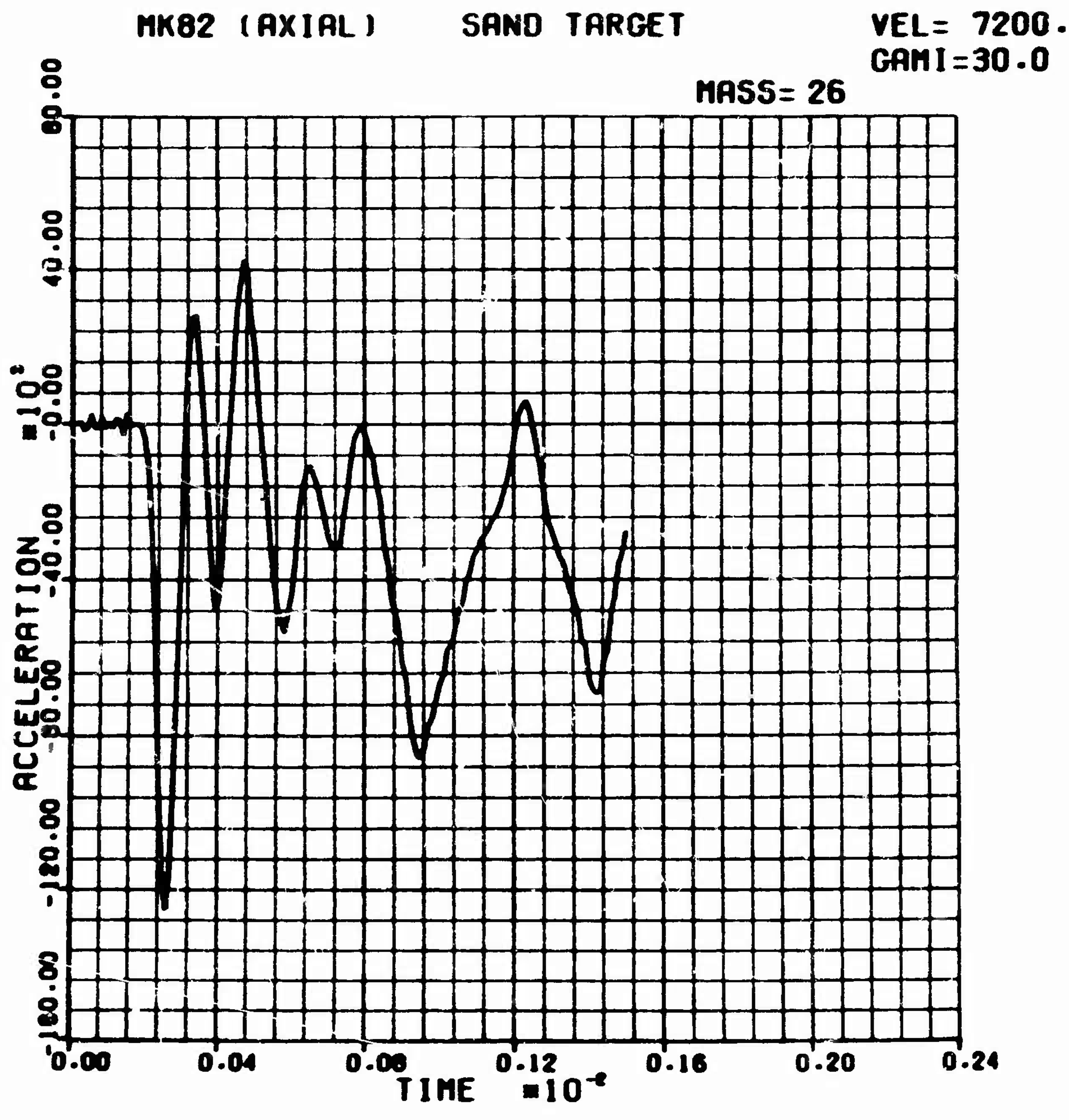

MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 24
ACCELERATION $*10^{3}$
50.00
-0.00
-50.00
-100.00
-150.00
-200.00
-250.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$


MK82 (AXIAL)
SAND TARGET
VEL=10800.
GAMI=70.0
MASS= 24
ACCELERATION $\times 10^{3}$
10.00
-40.00
-90.00
-140.00
-190.00
-240.00
-290.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $\times 10^{-2}$

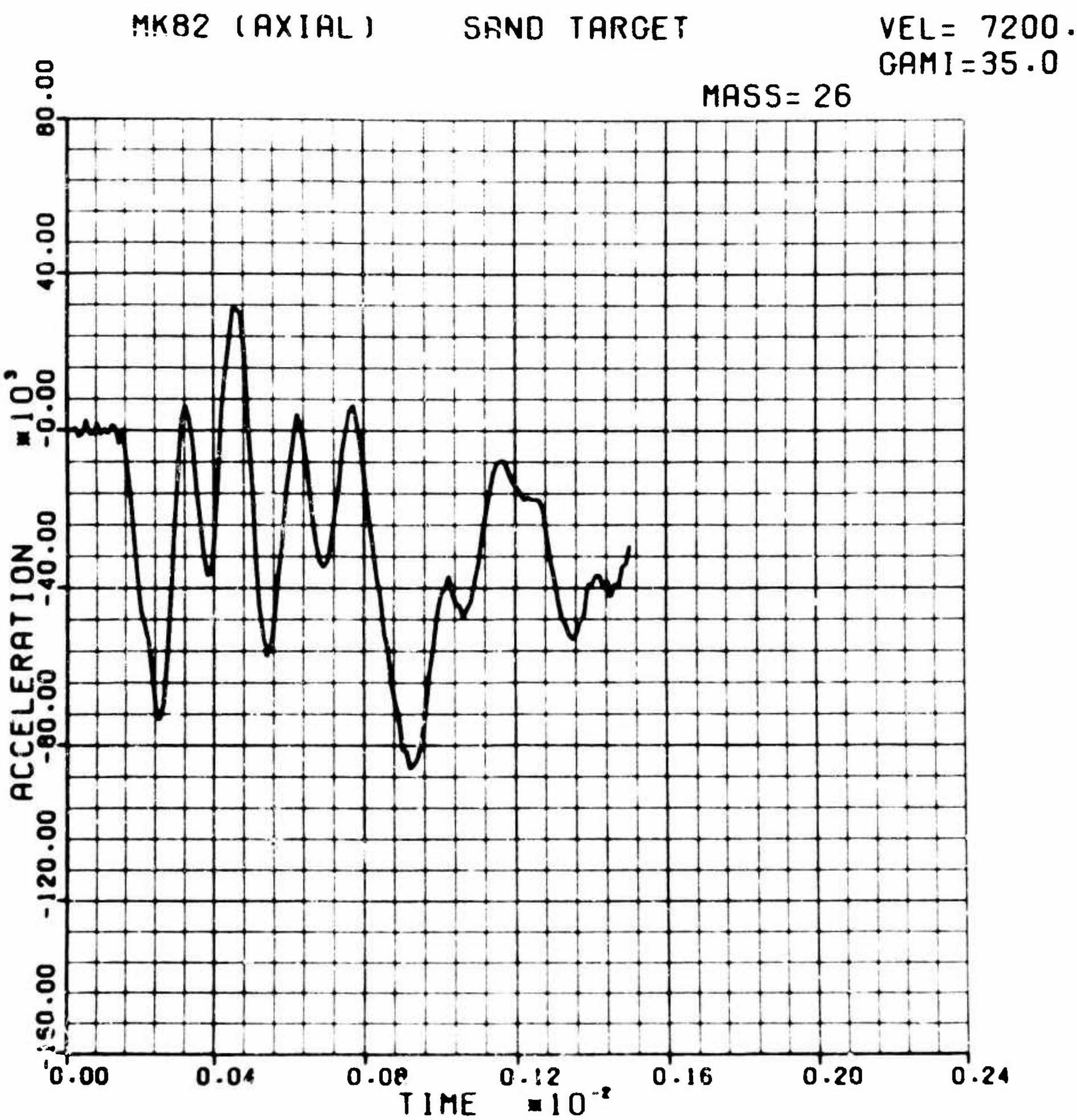


MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 26
ACCELERATION ×10³
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
TIME ×10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

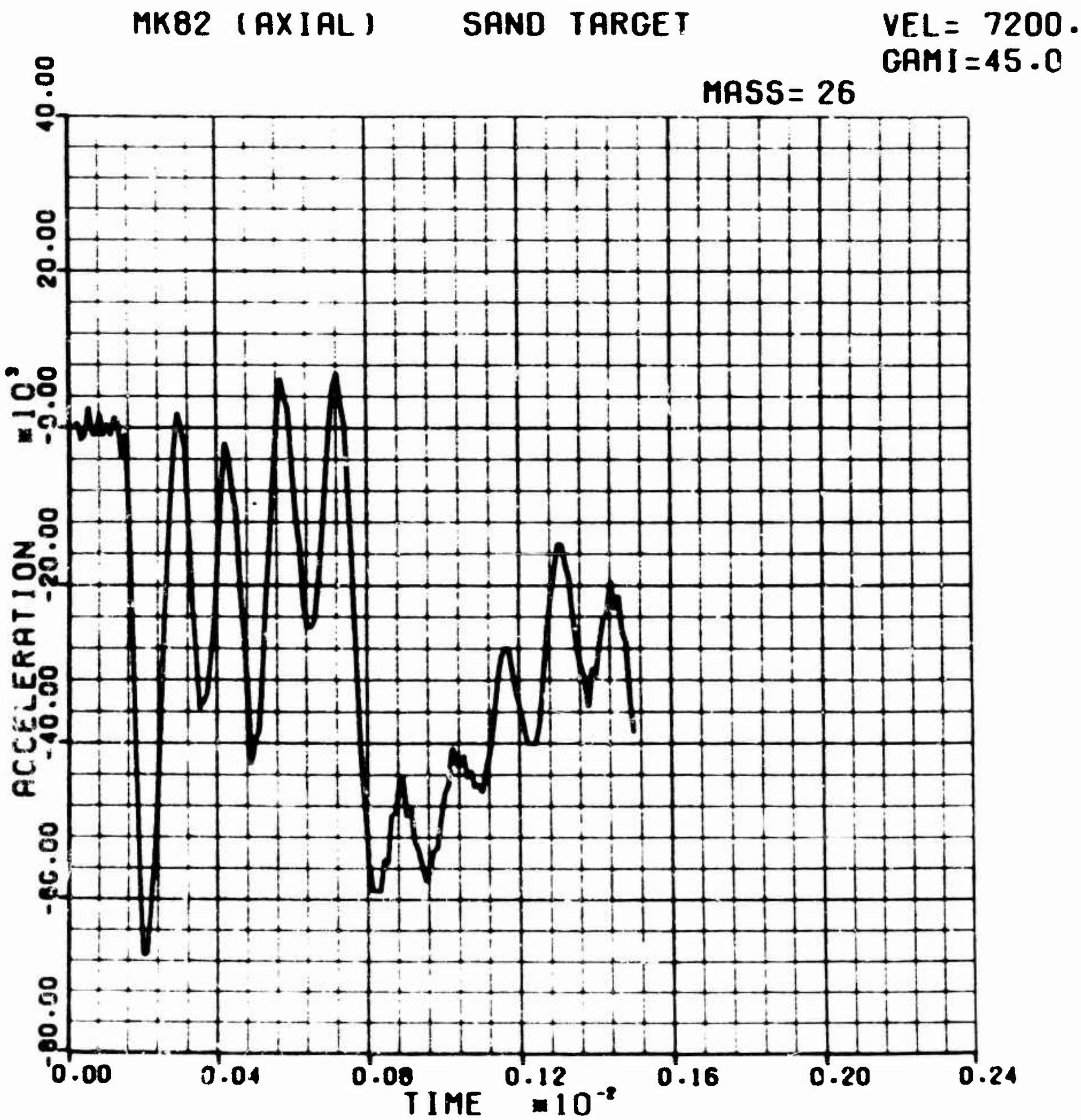

MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 26
ACCELERATION *10³
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



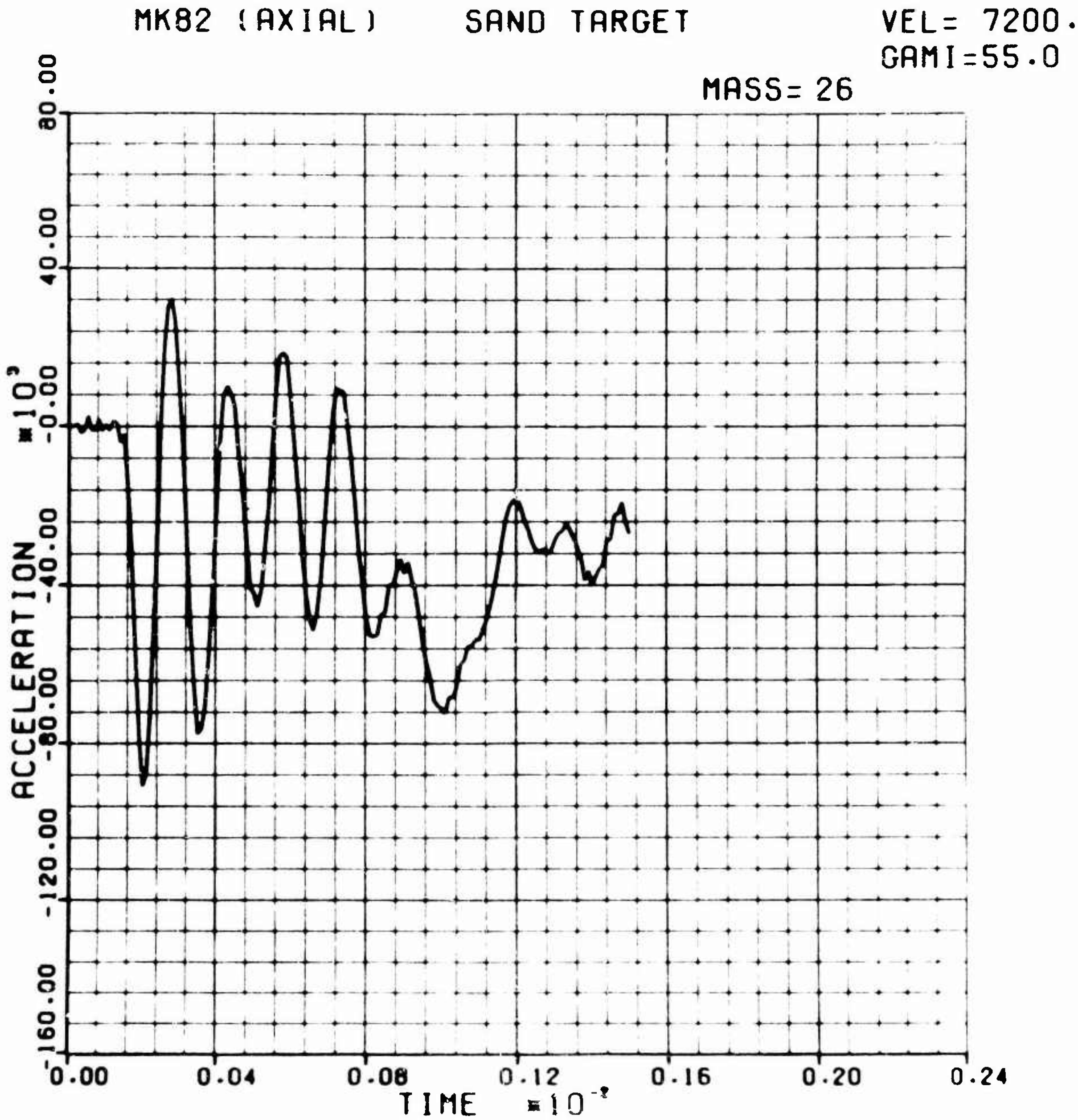
MK82 (AXIAL) SAND TARGET
VEL= 7200.
GAMI=30.0
MASS= 26
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
ACCELERATION *10³
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

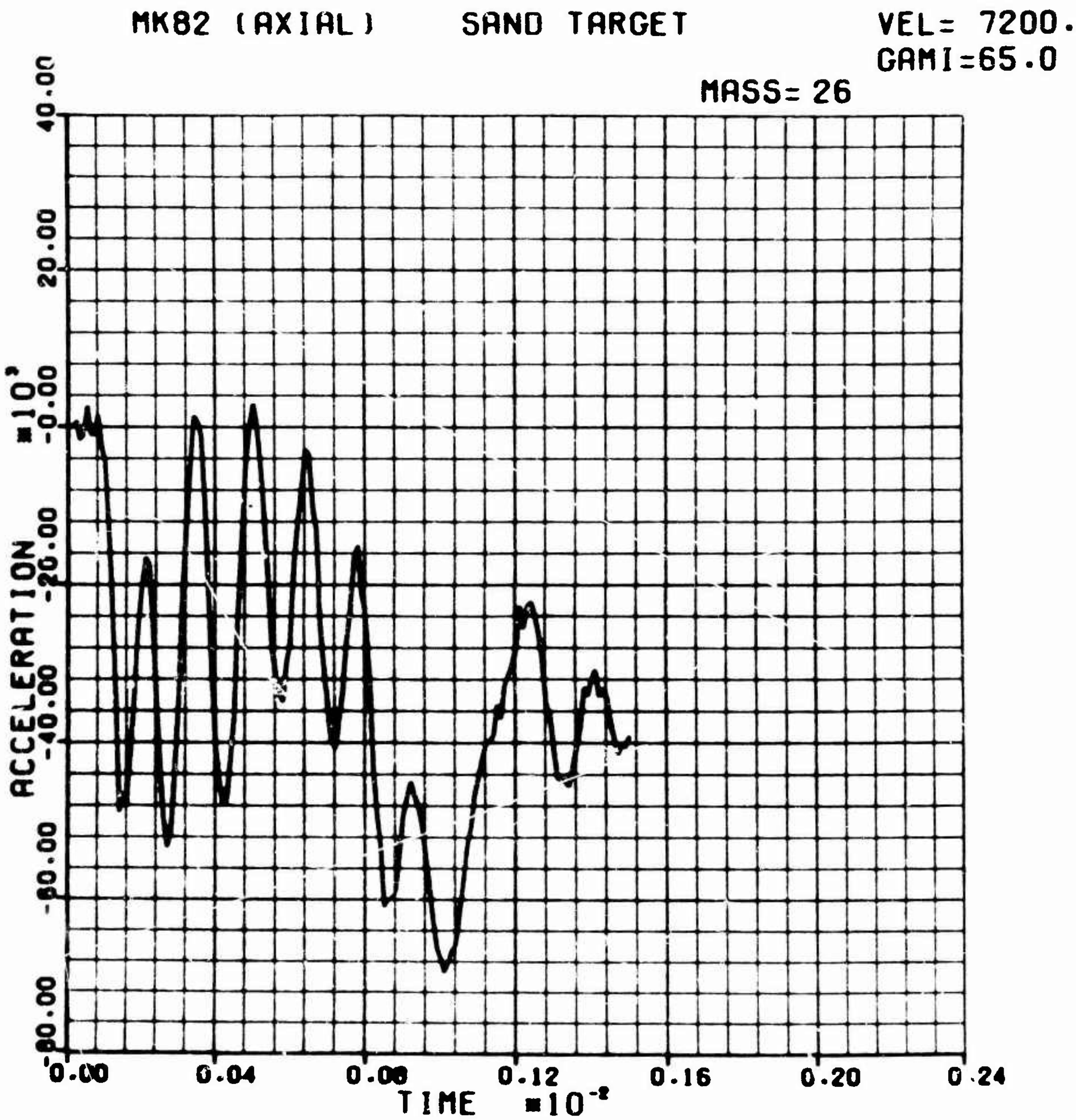


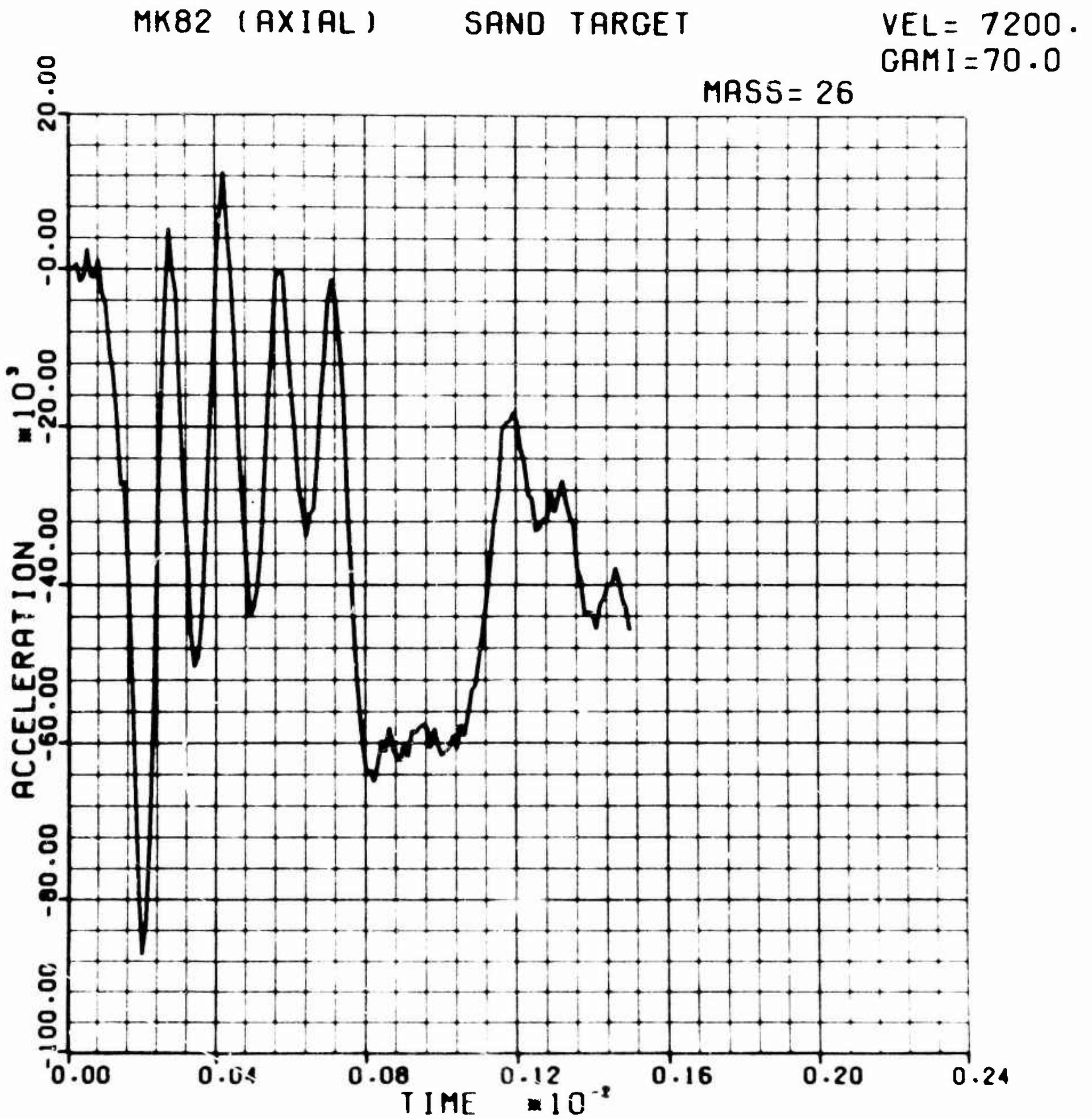
MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 26
ACCELERATION ×10³
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

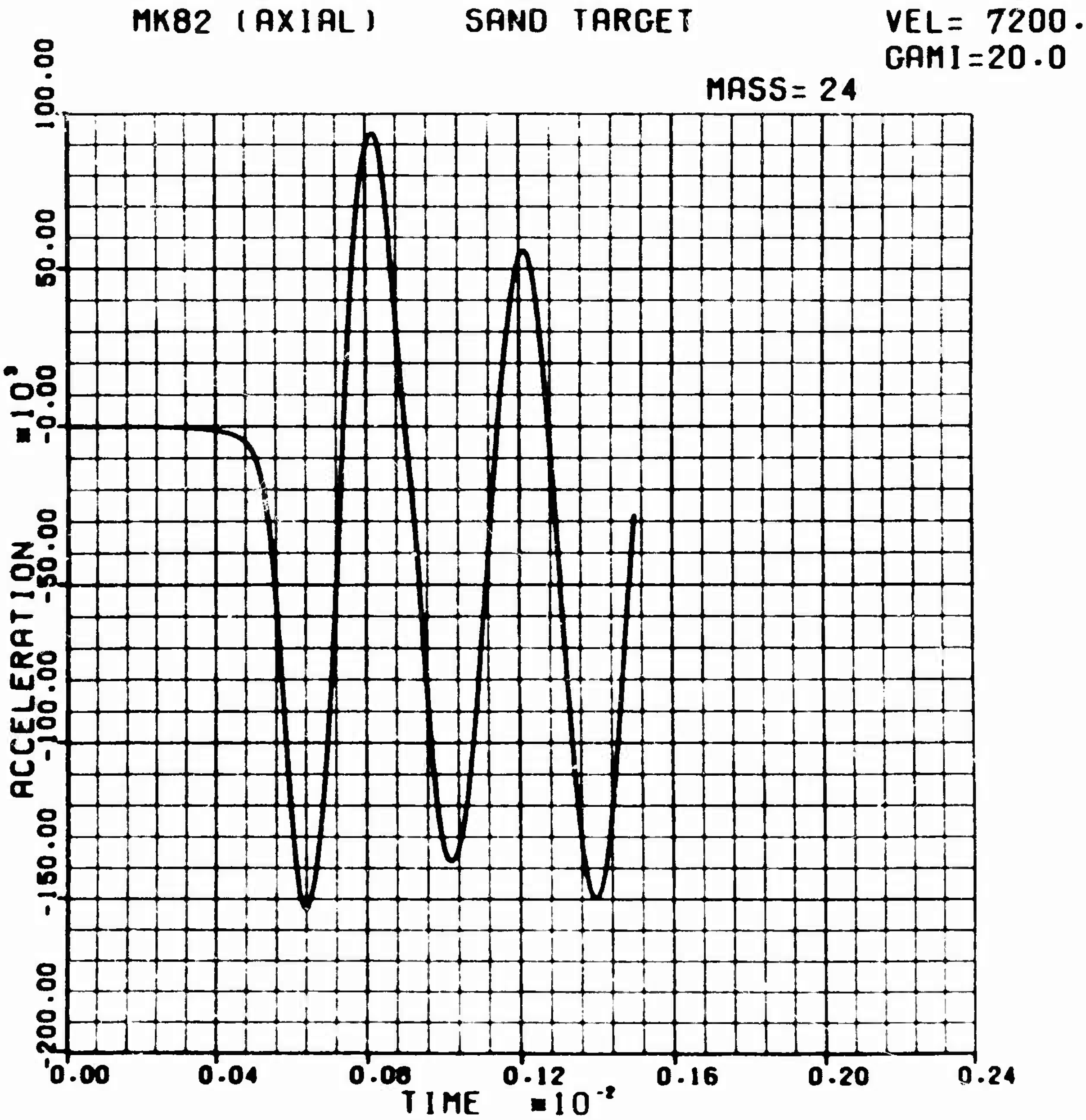


MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 26
ACCELERATION *10³
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

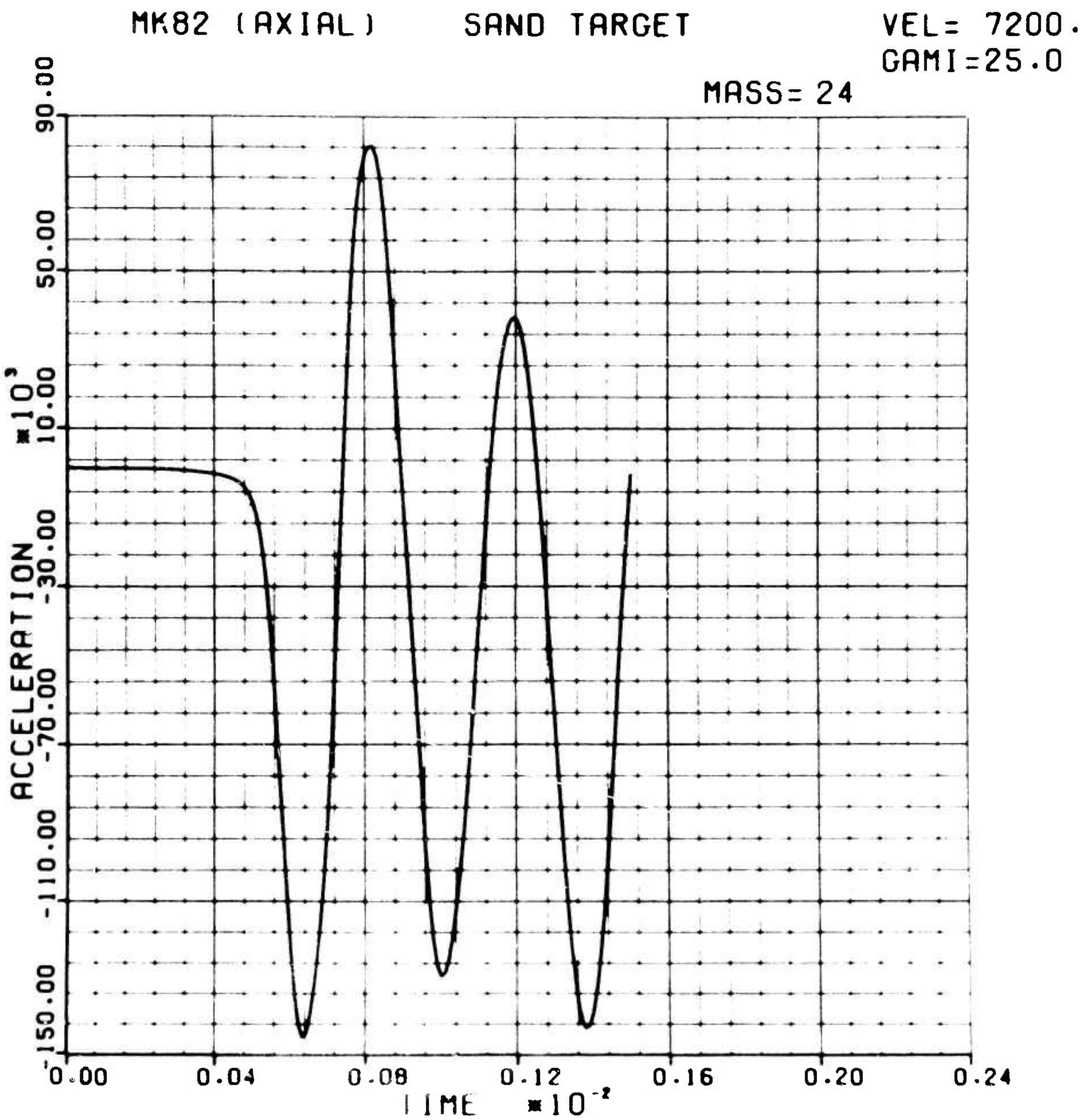

MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 26
ACCELERATION $*10^3$
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-1}$


MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 26
ACCELERATION *10³
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

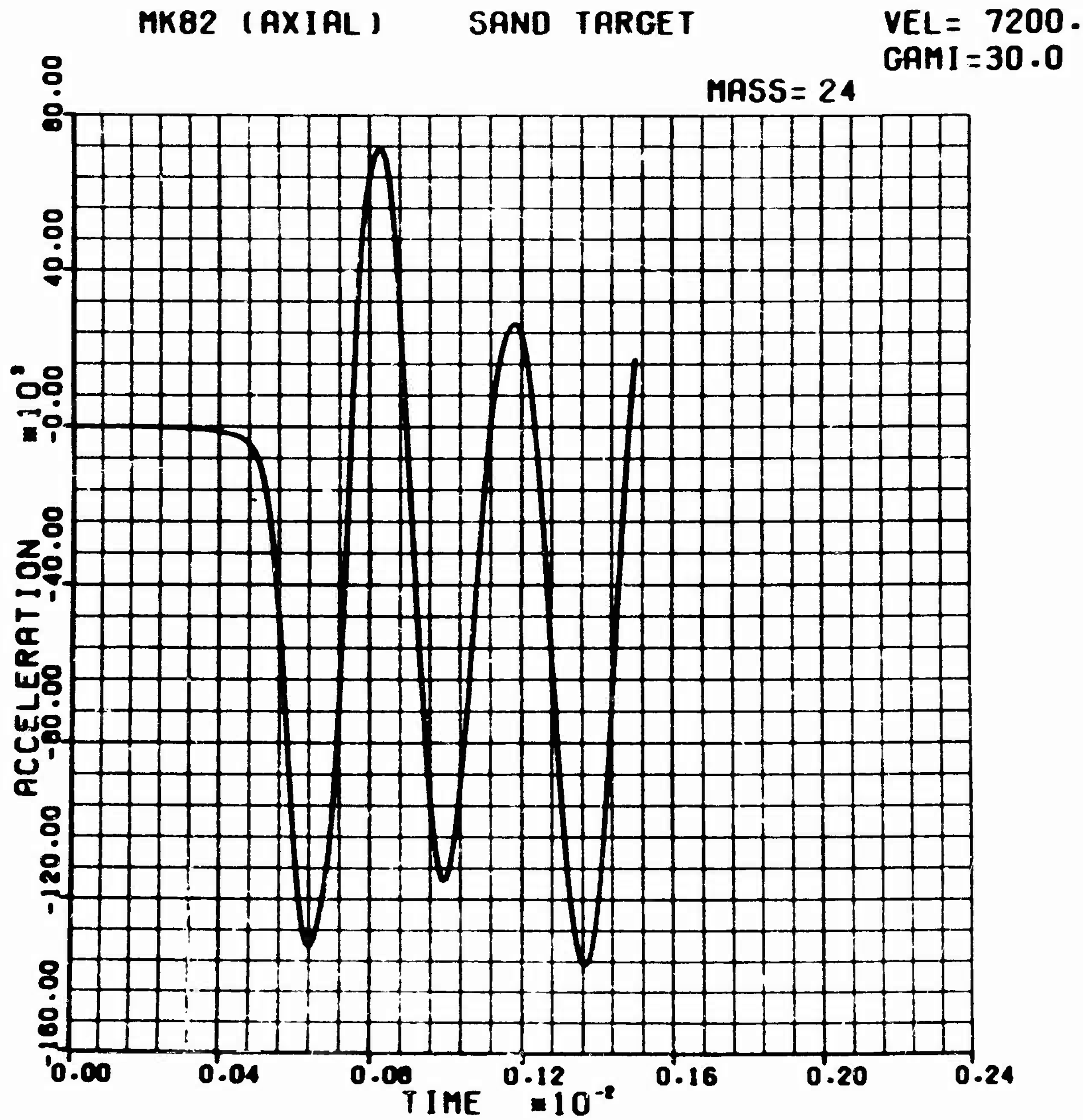

MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 26
ACCELERATION *10³
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

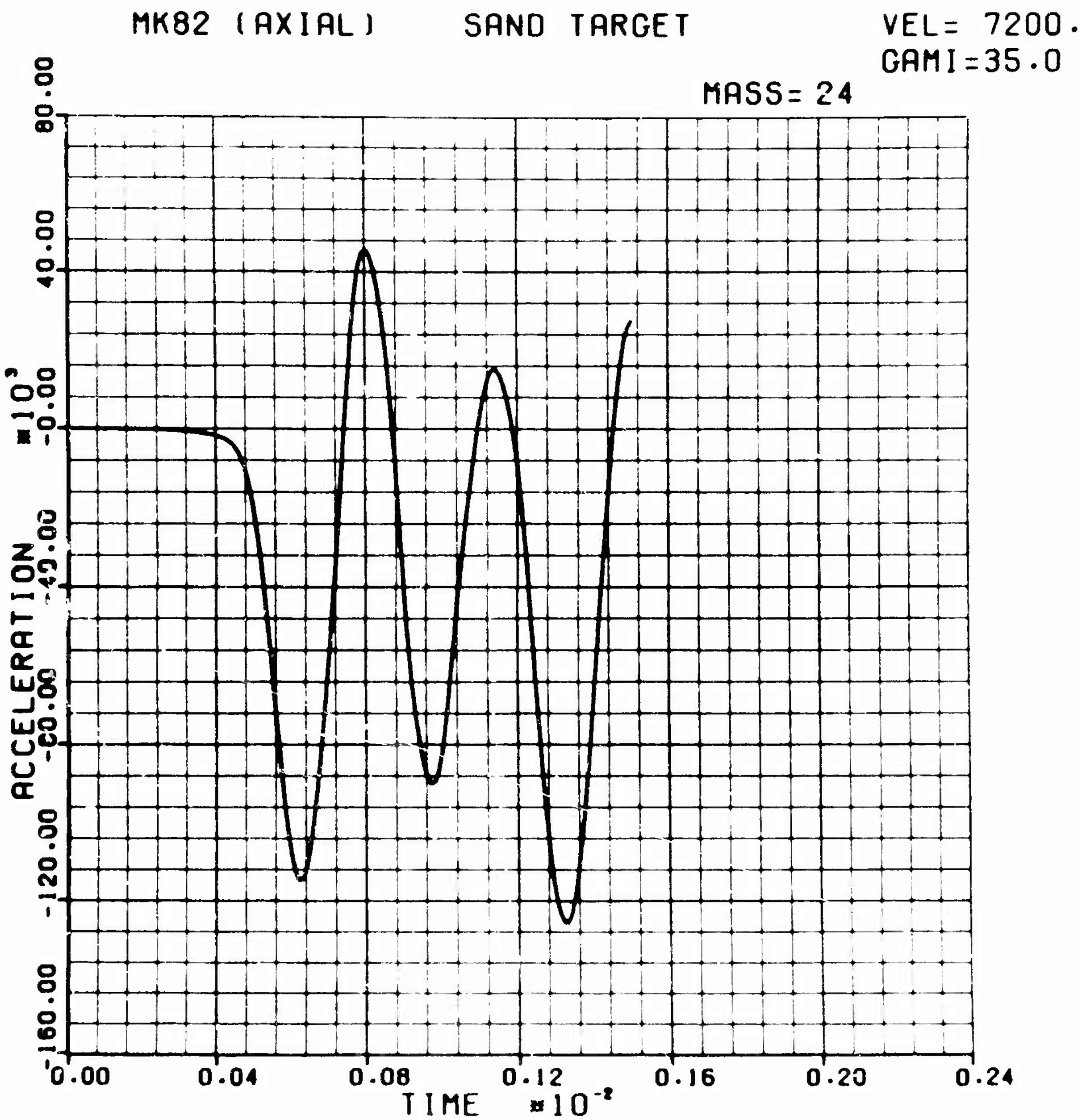


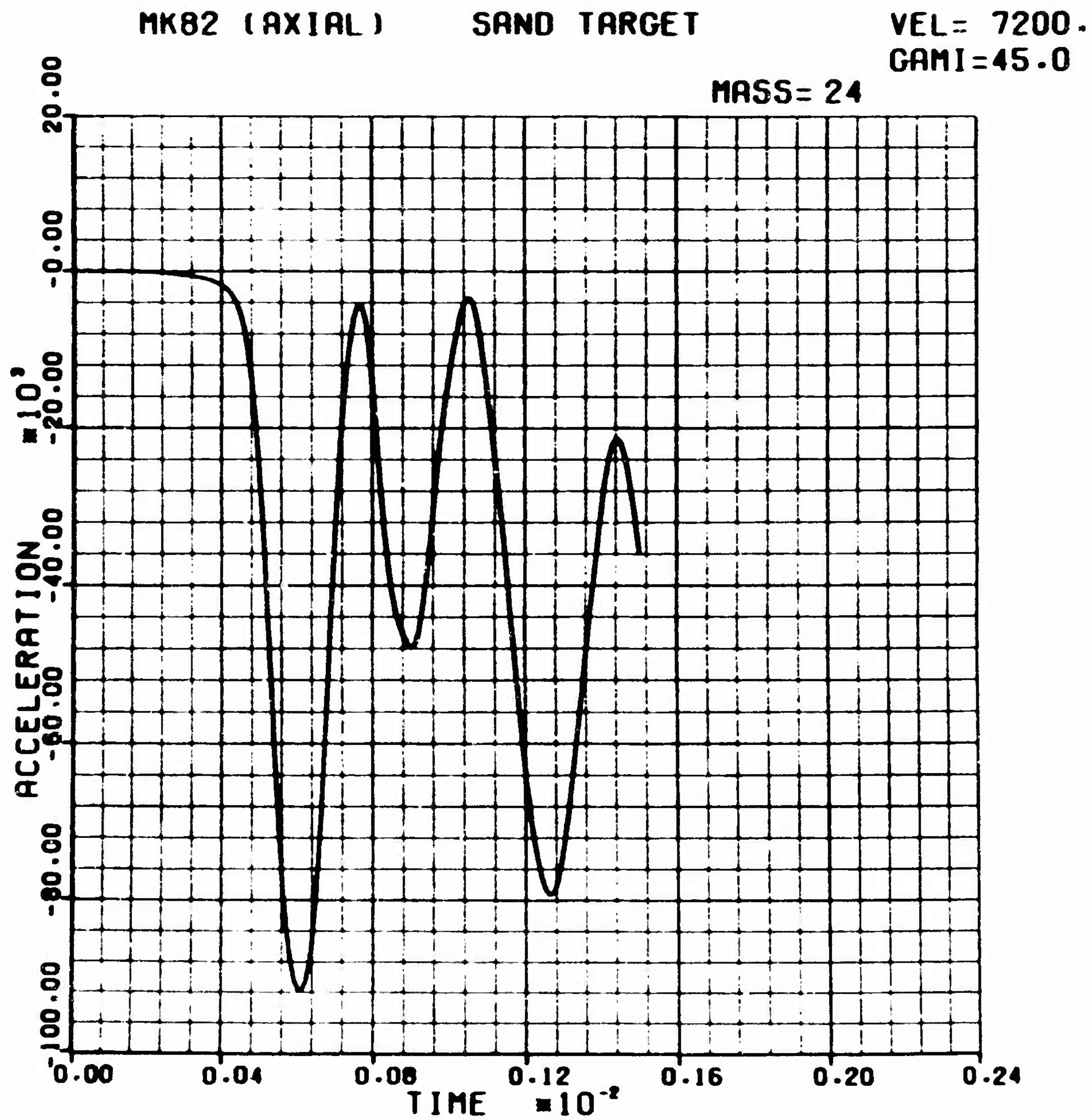
MK82 (AXIAL) SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 24
100.00
50.00
-0.00
-50.00
-100.00
-150.00
-200.00
ACCELERATION *10³
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

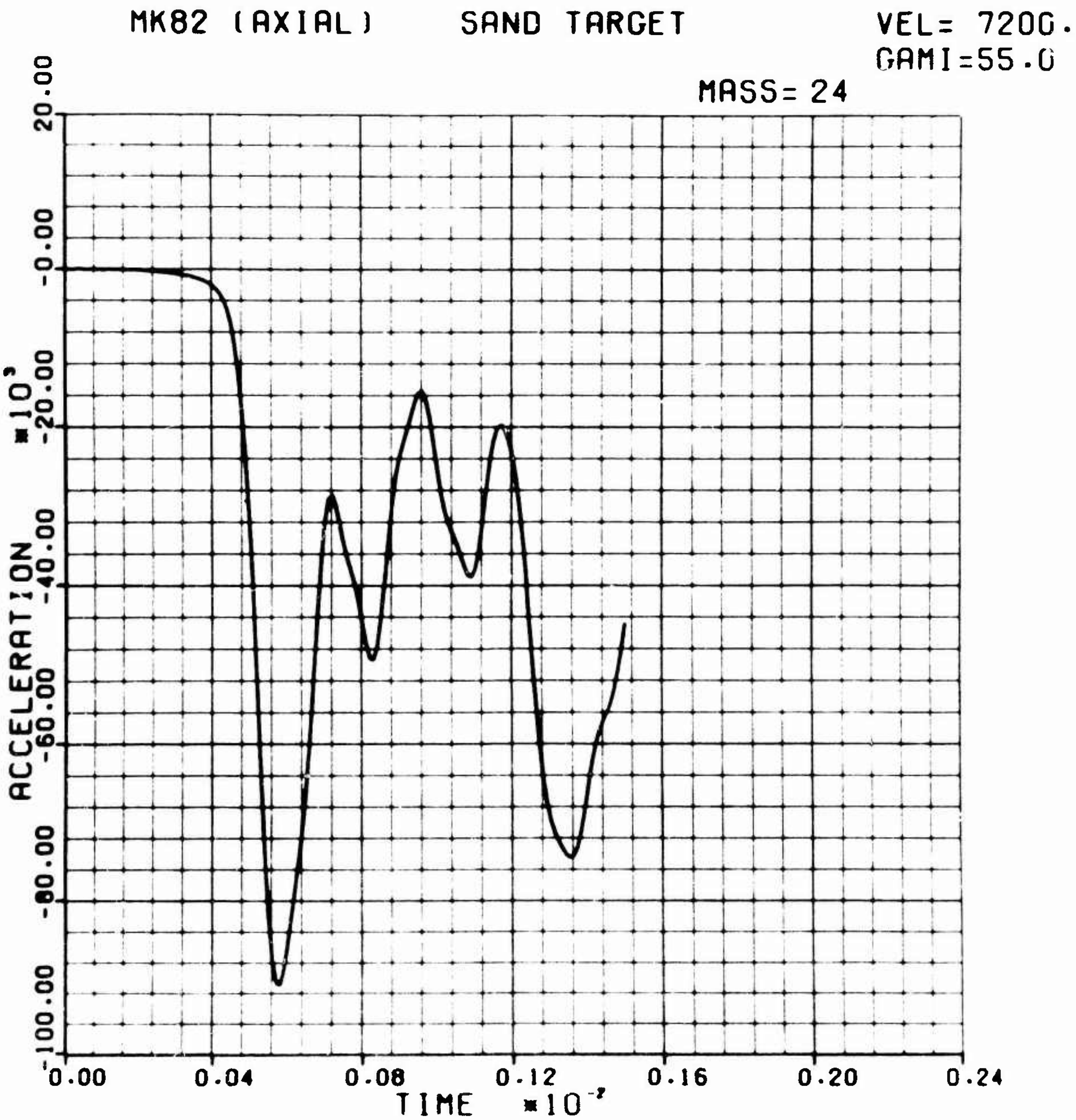


MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 24
ACCELERATION *10^3
90.00
50.00
10.00
-30.00
-70.00
-110.00
-150.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

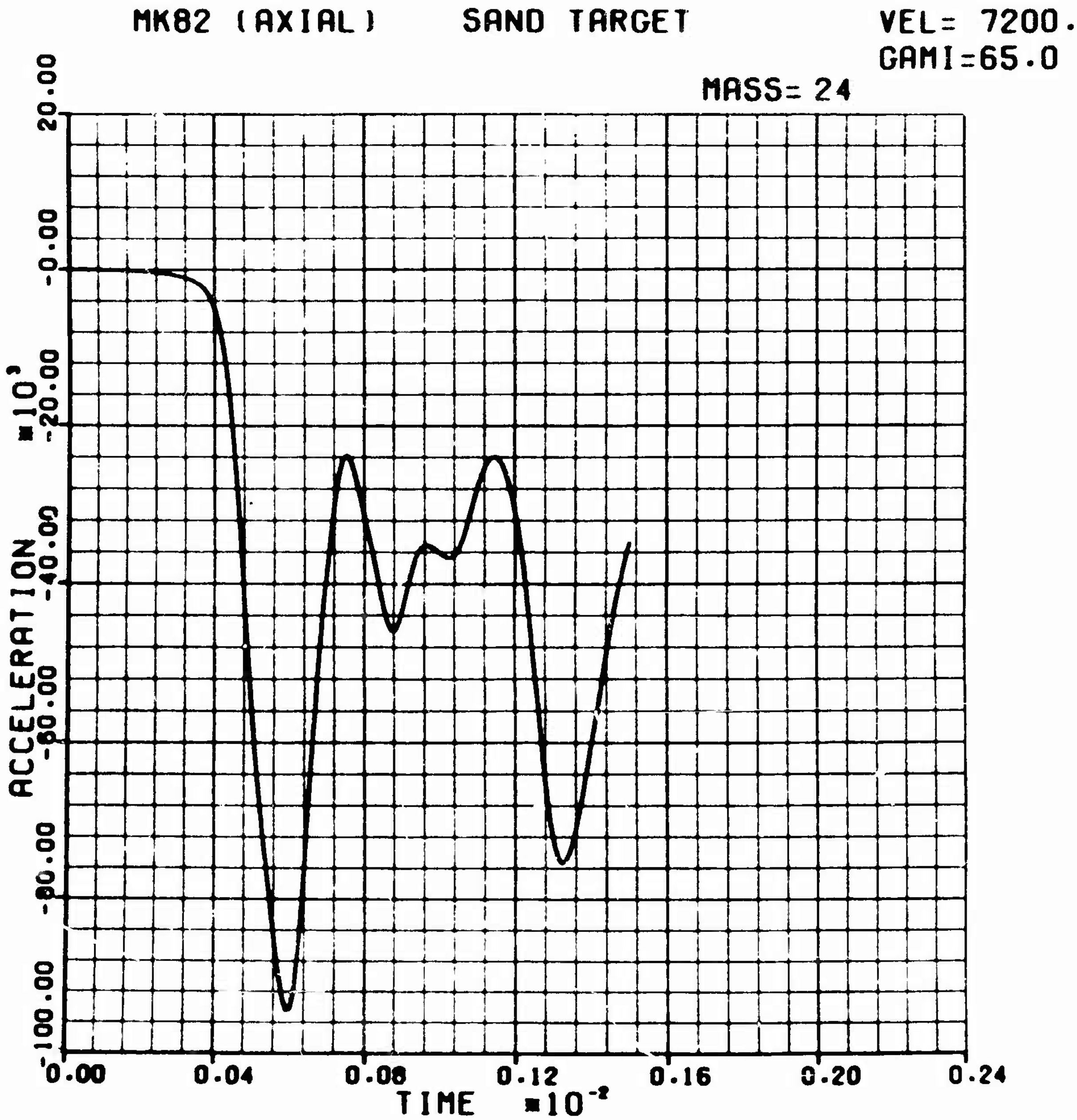

MK82 (AXIAL) SAND TARGET
VEL= 7200.
GAMI=30.0
MASS= 24
ACCELERATION $*10^{3}$
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$

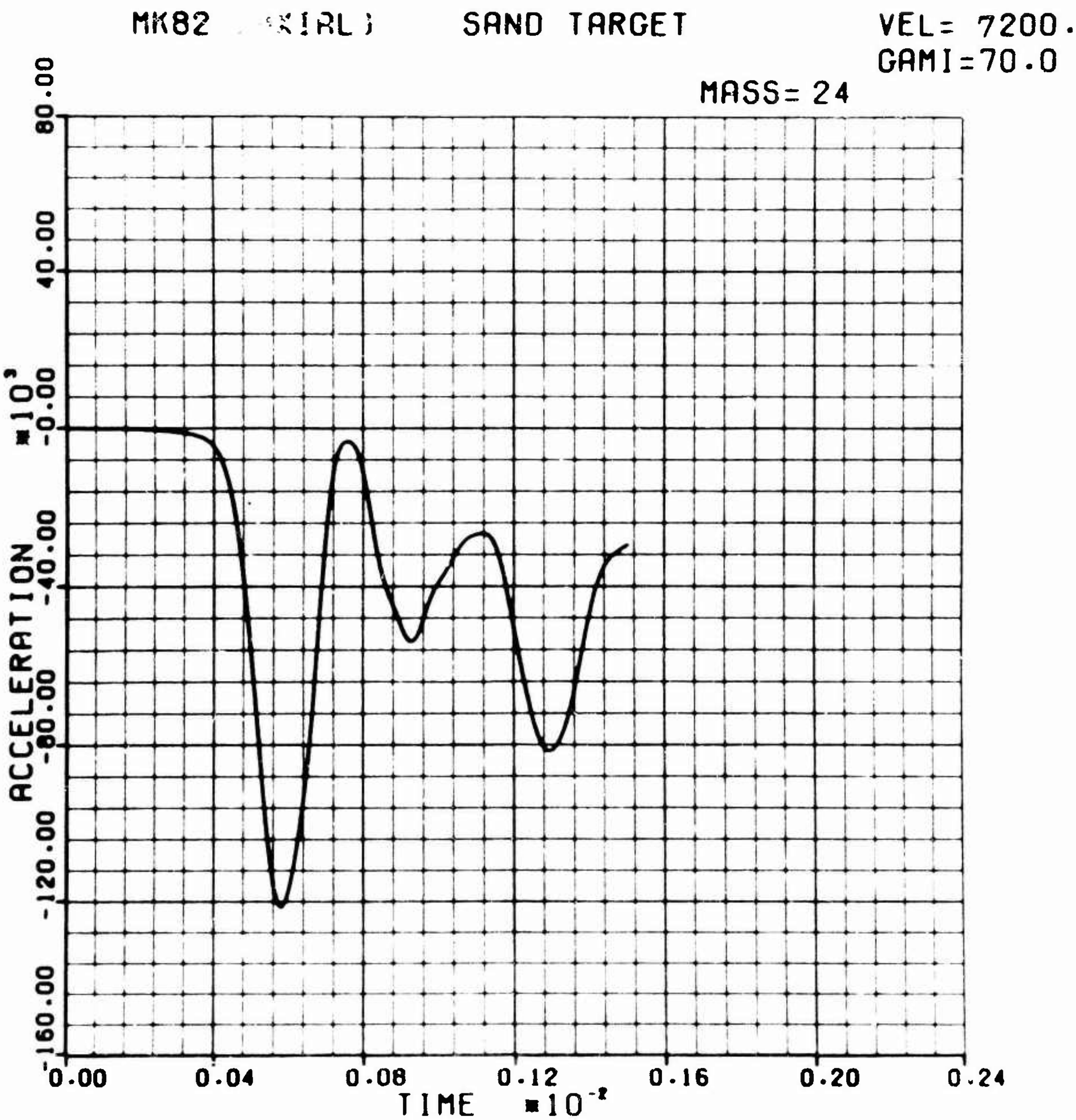

MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 24
ACCELERATION *10^3
TIME *10^-2
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24

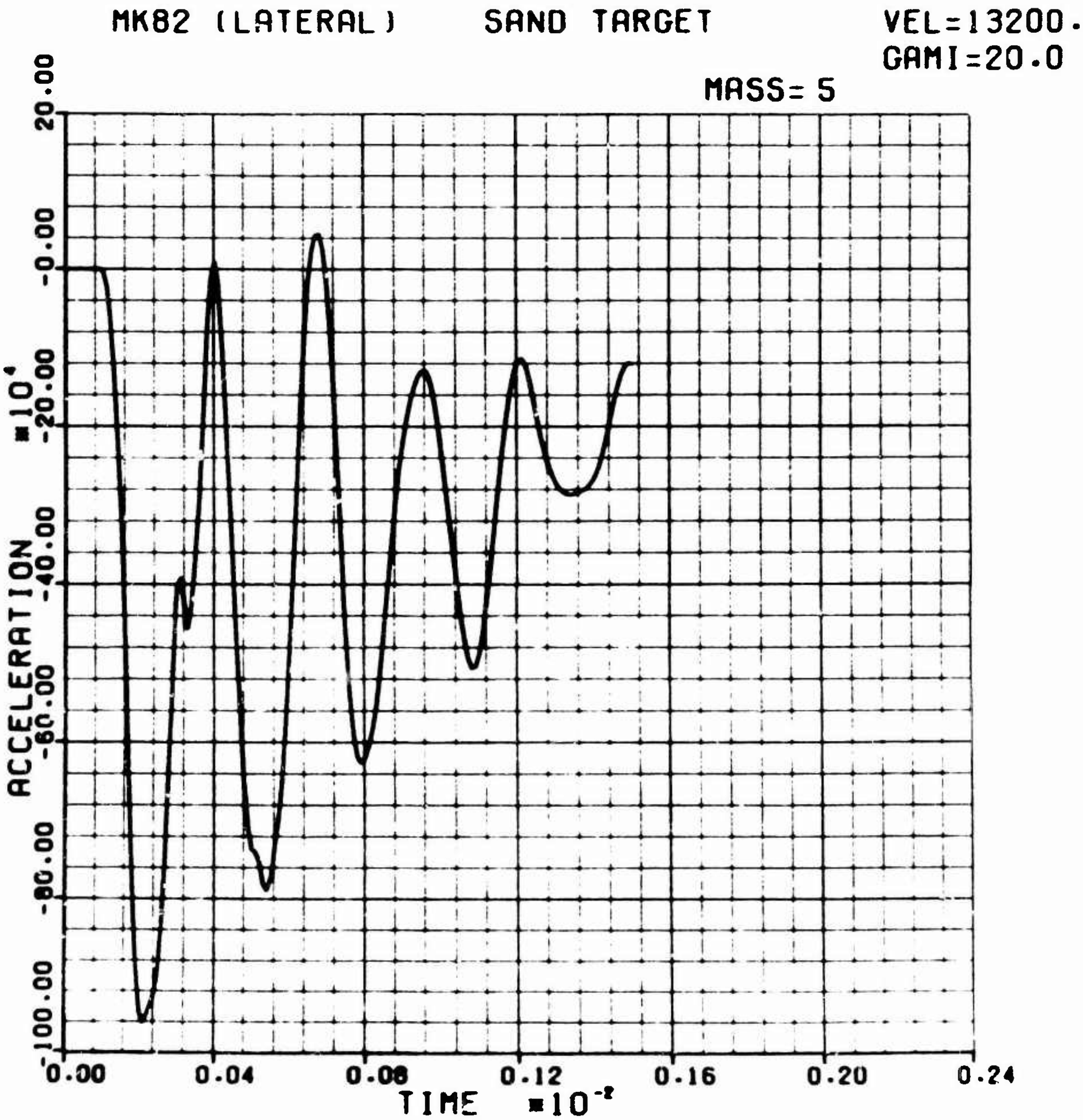

MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 24
ACCELERATION *10³
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

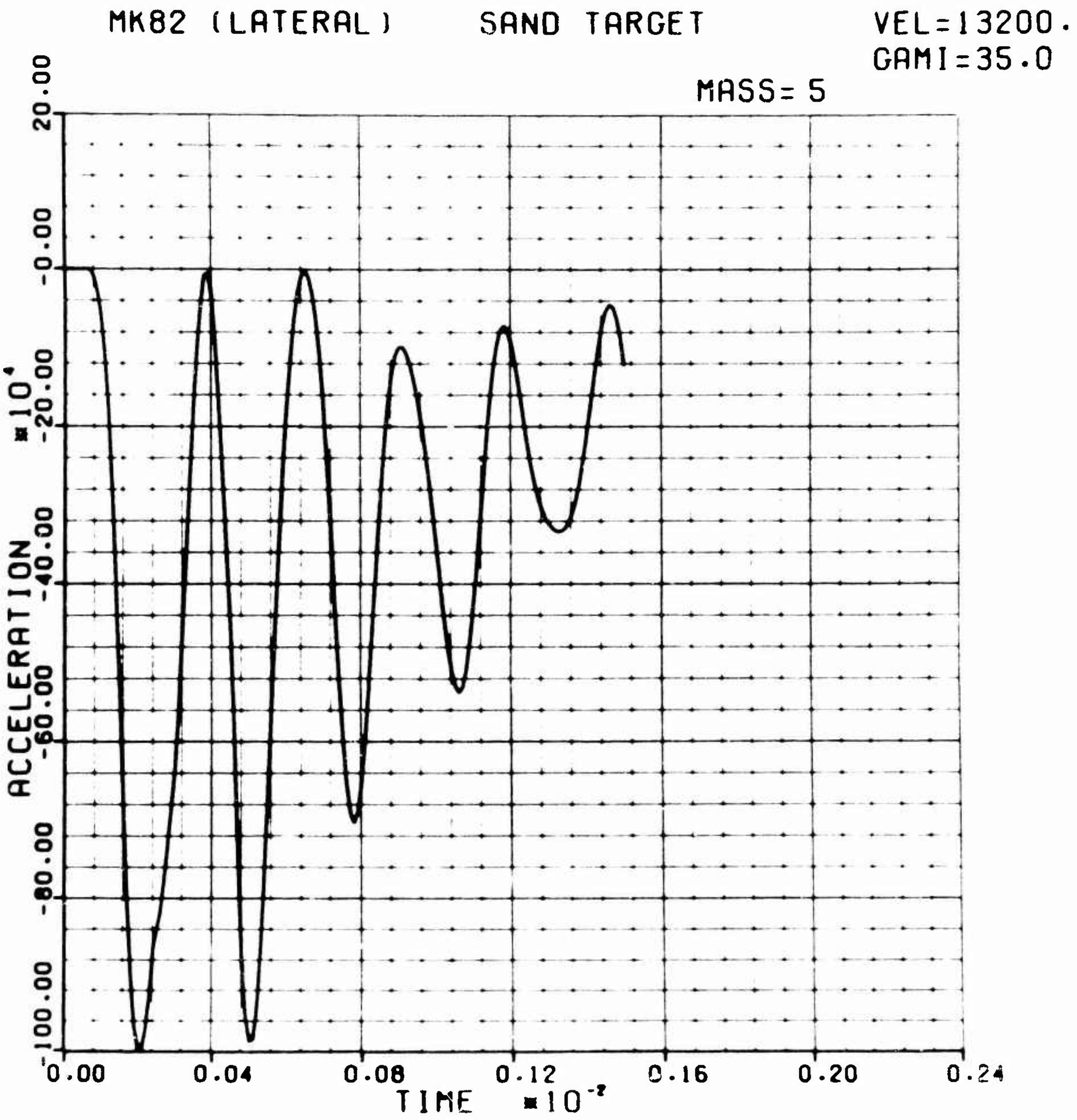


MK82 (AXIAL)
SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 24
ACCELERATION *10³
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

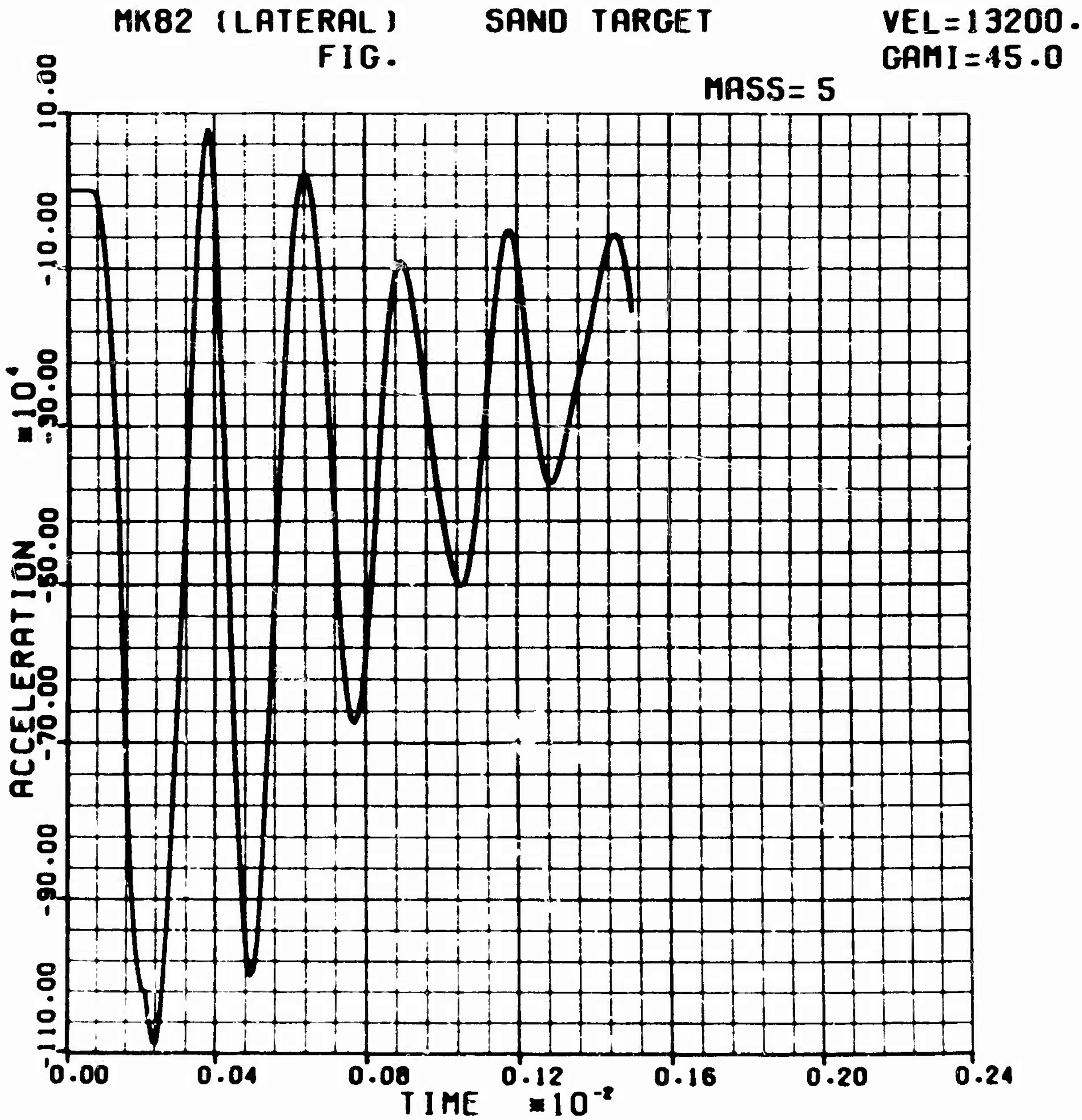

MK82 (AXIAL) SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 24
ACCELERATION $*10^3$
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$

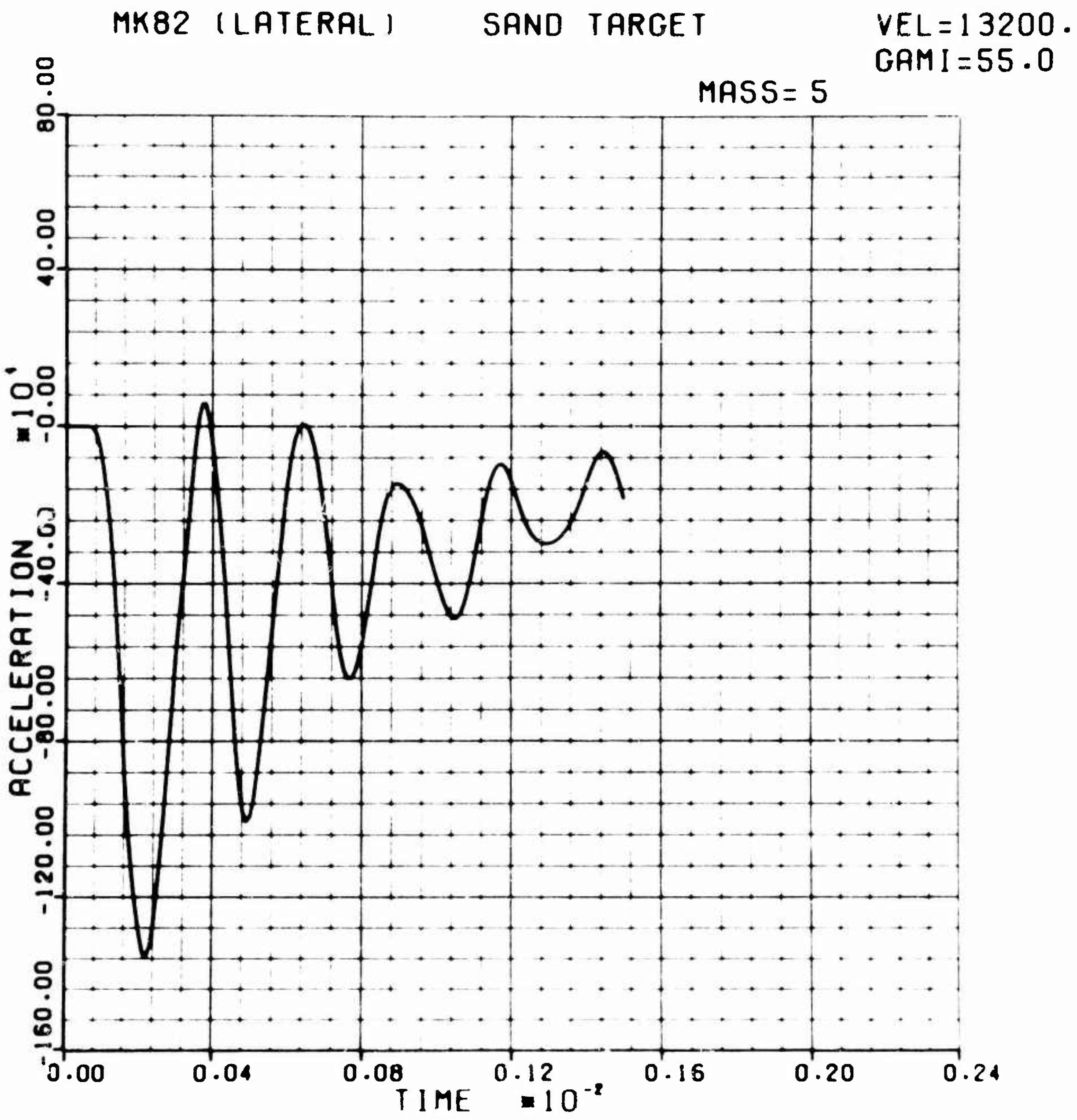

MK82 (XIRL) SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 24
ACCELERATION *10^3
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
TIME *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24

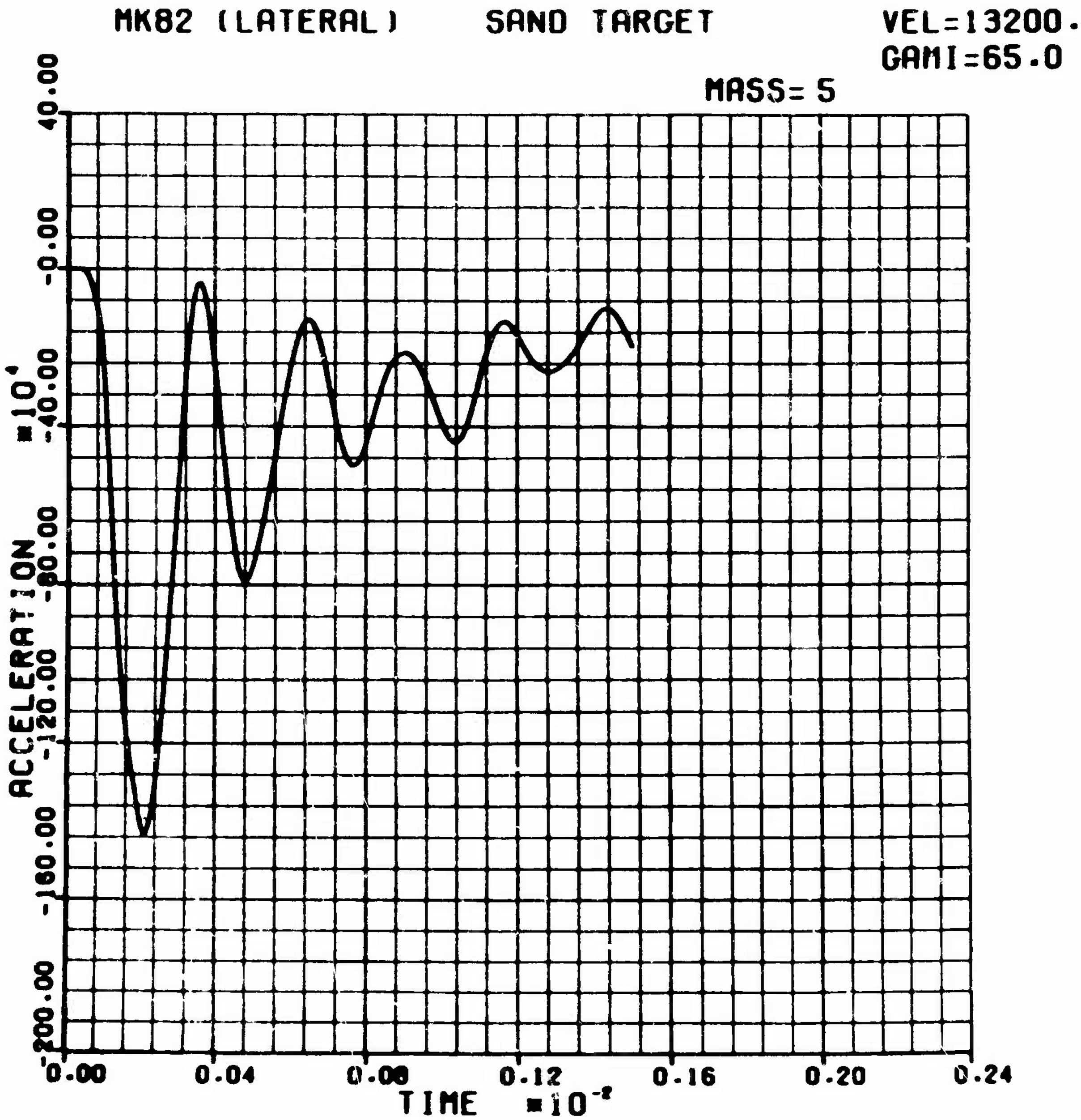

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 5
ACCELERATION *10⁴
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



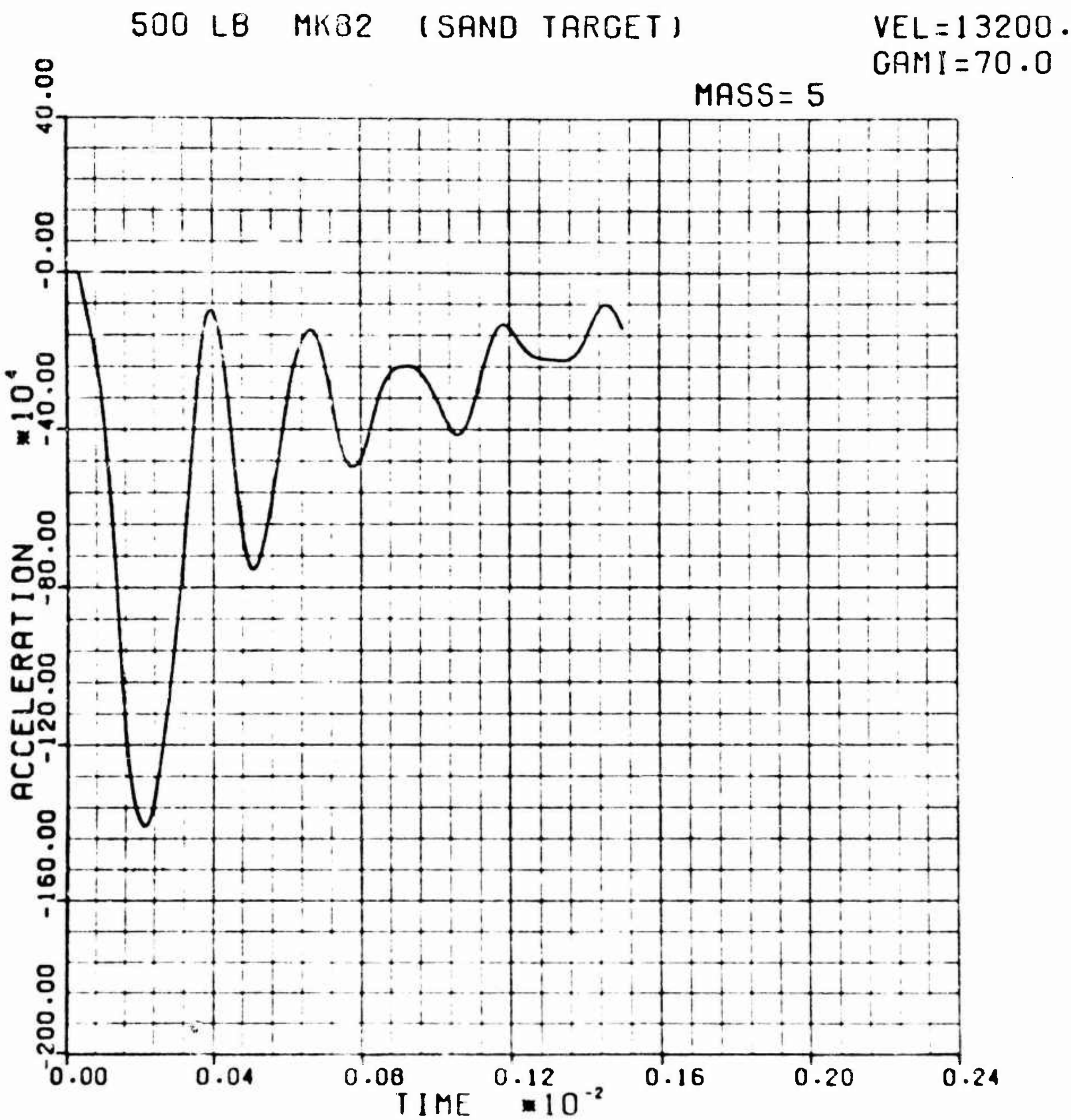
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=35.0
MASS= 5
ACCELERATION ×10⁴
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

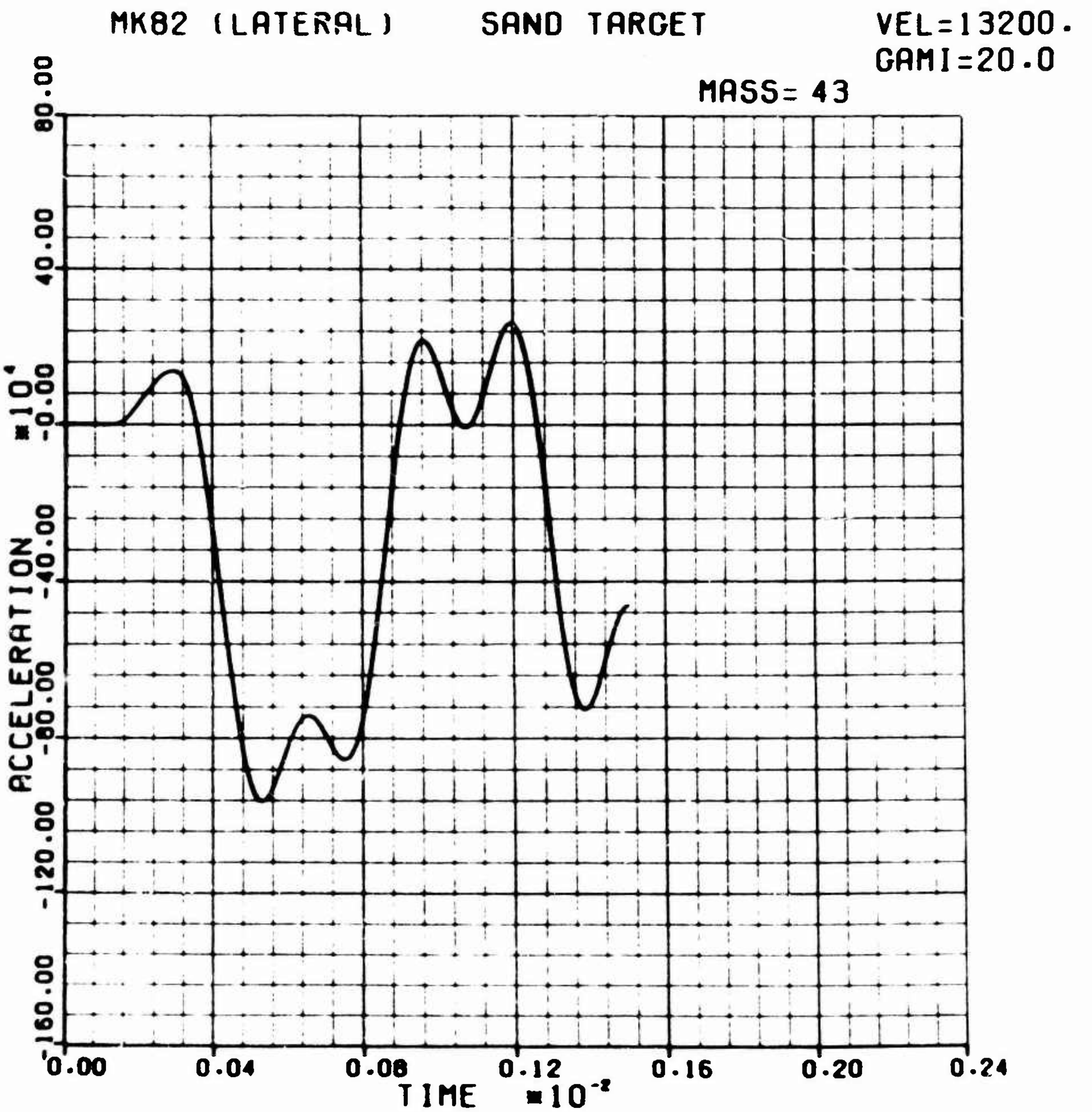

MK82 (LATERAL)
SAND TARGET
VEL=13200.
FIG.
GAMI=45.0
MASS= 5
ACCELERATION $*10^4$
10.00
-10.00
-30.00
-50.00
-70.00
-90.00
-110.00
TIME $*10^{-2}$
0.00
0.04
0.08
0.12
0.16
0.20
0.24

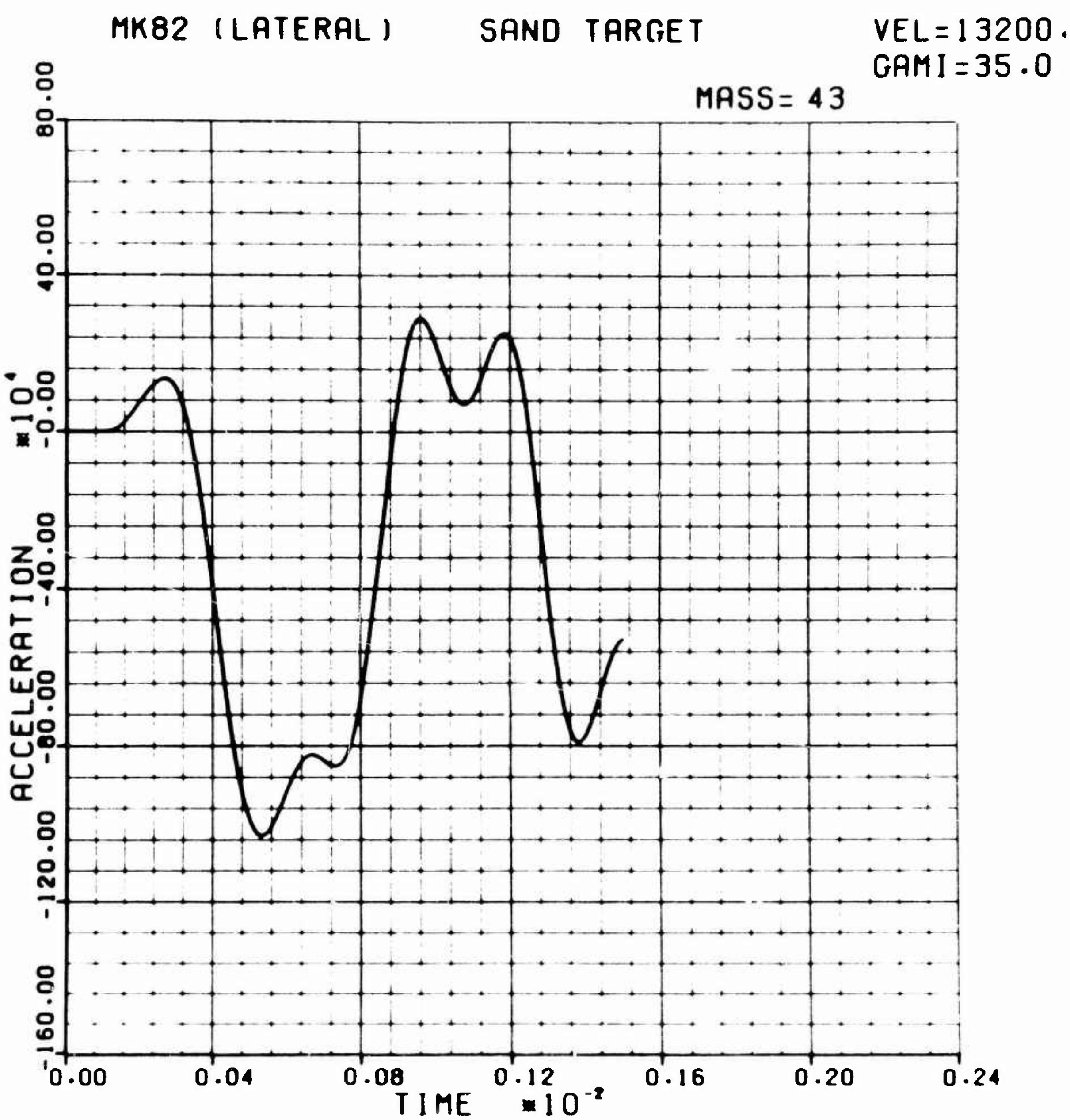

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 5
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
ACCELERATION
*10^1
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

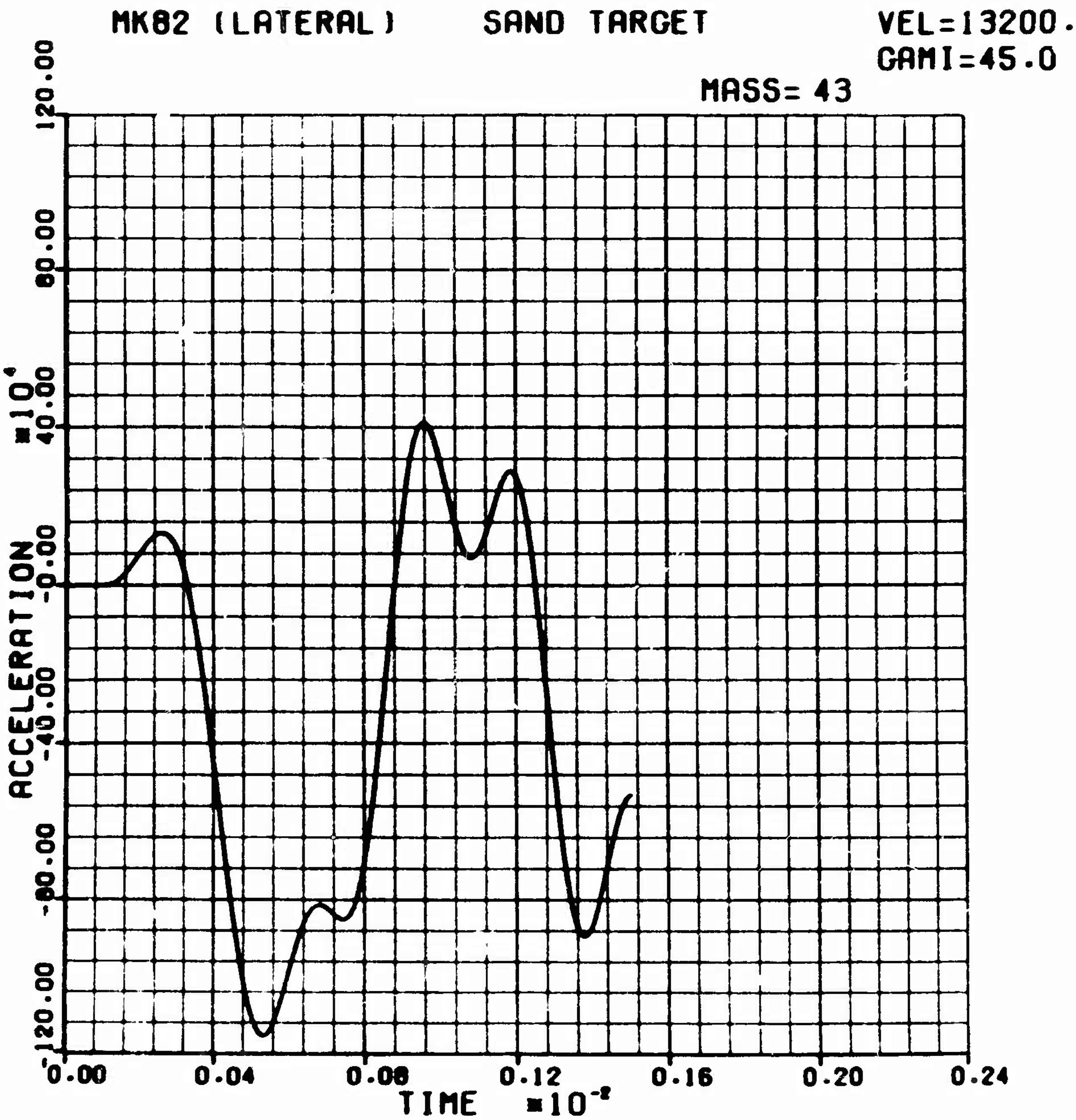


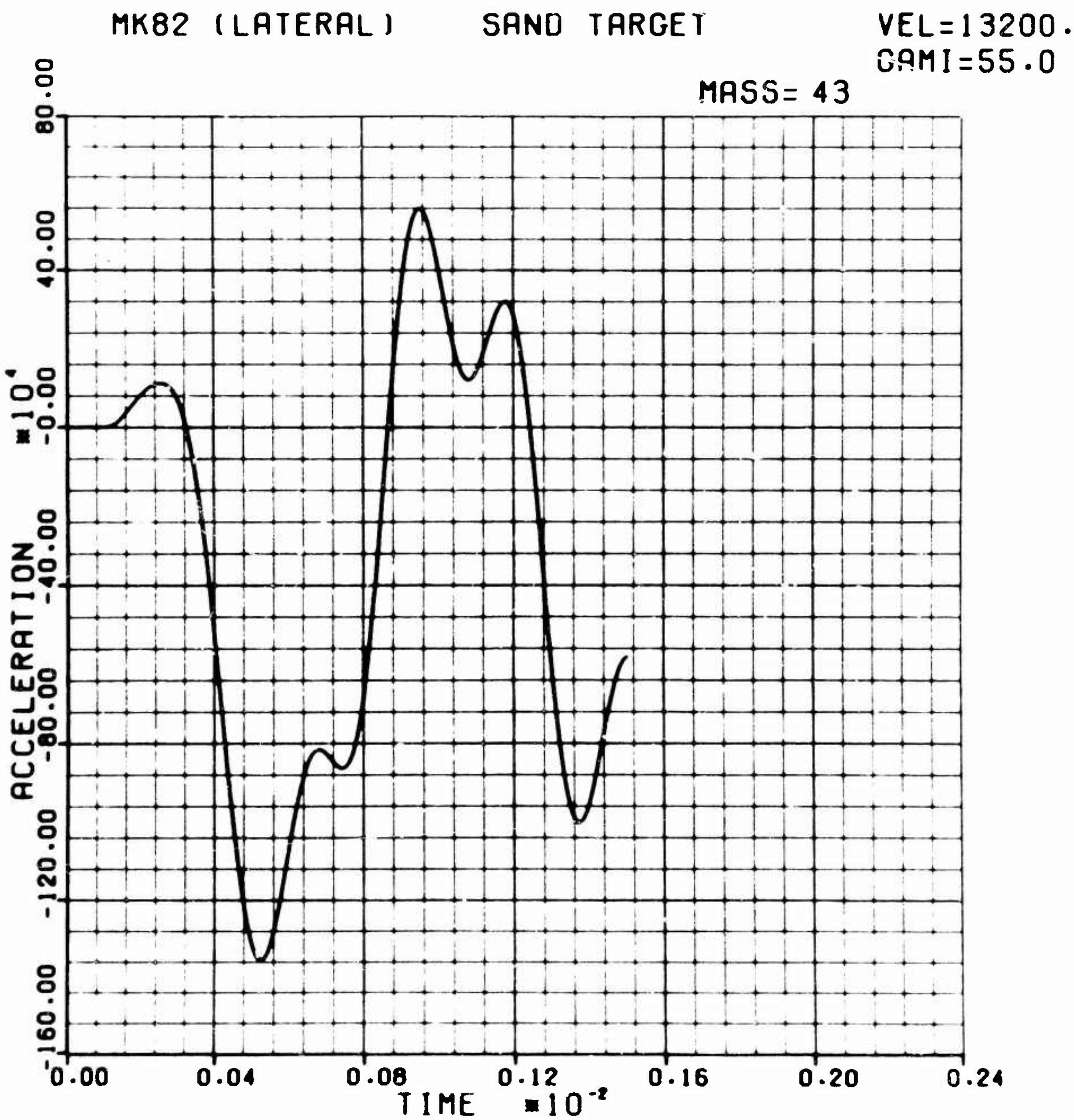
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 5
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
-200.00
ACCELERATION $\times 10^4$
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $\times 10^{-2}$

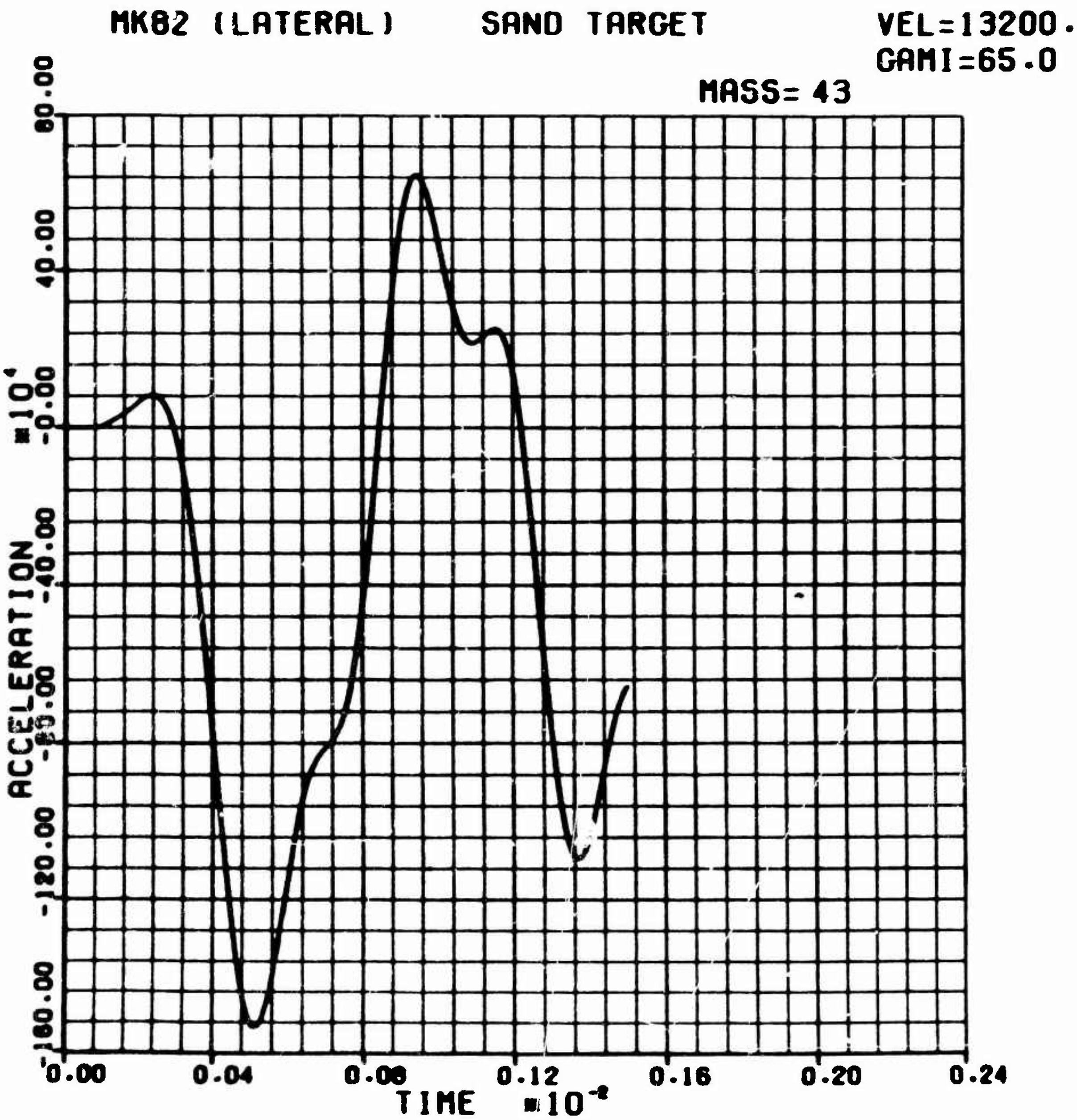

500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 5
ACCELERATION *10^4
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
-200.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

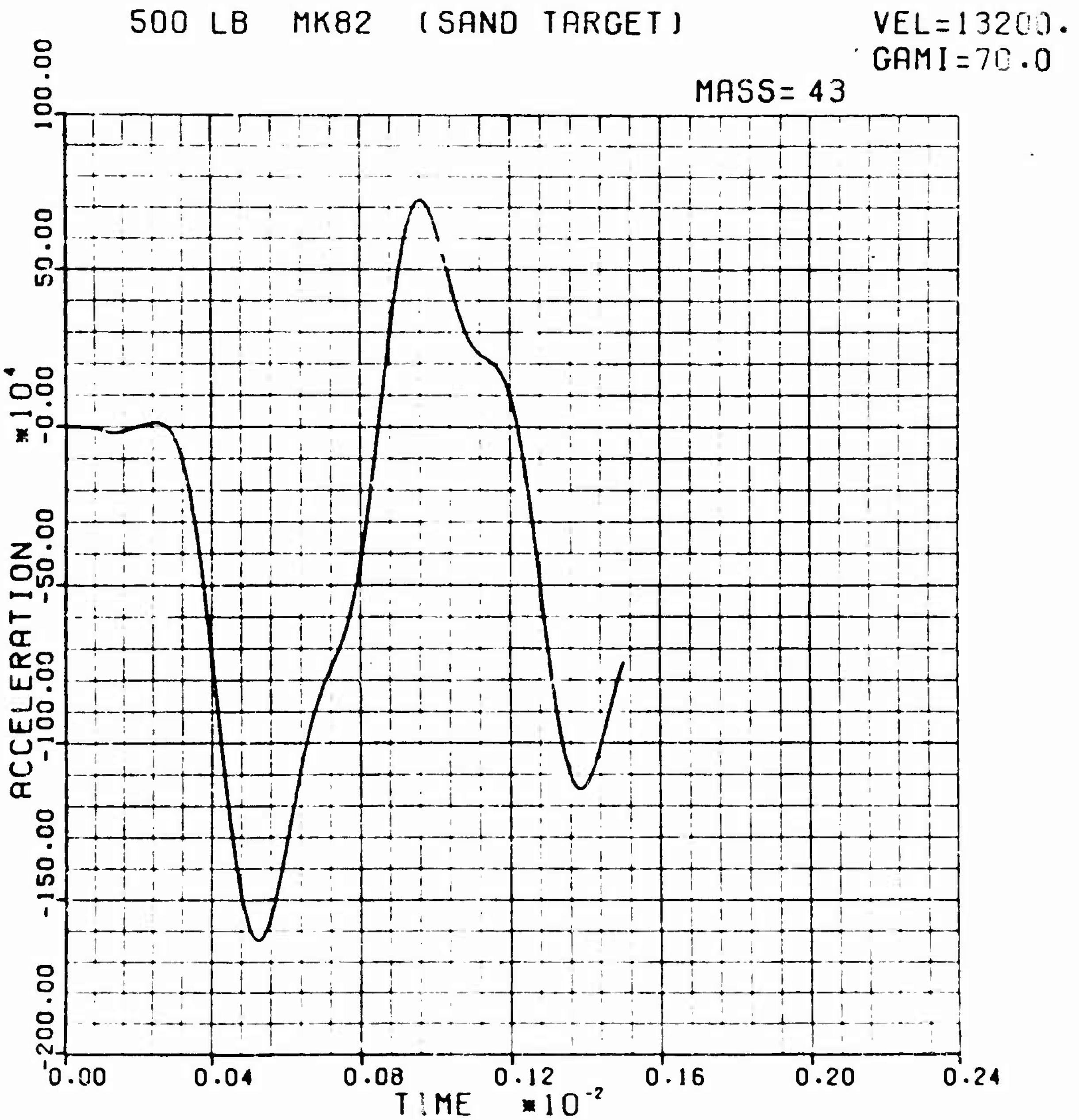

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 43
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
ACCELERATION *10⁴
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

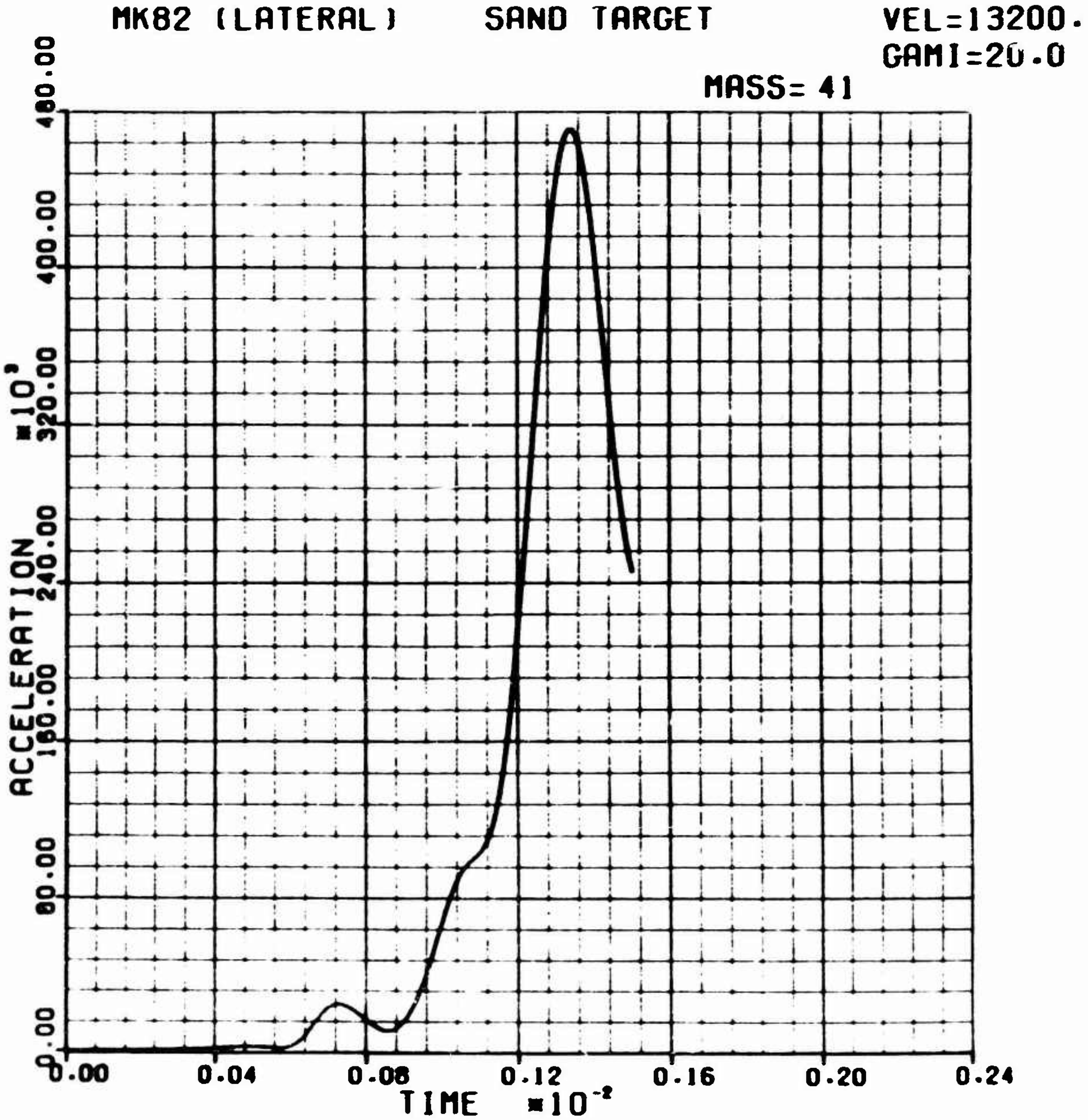

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=35.0
MASS= 43
ACCELERATION *10^4
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

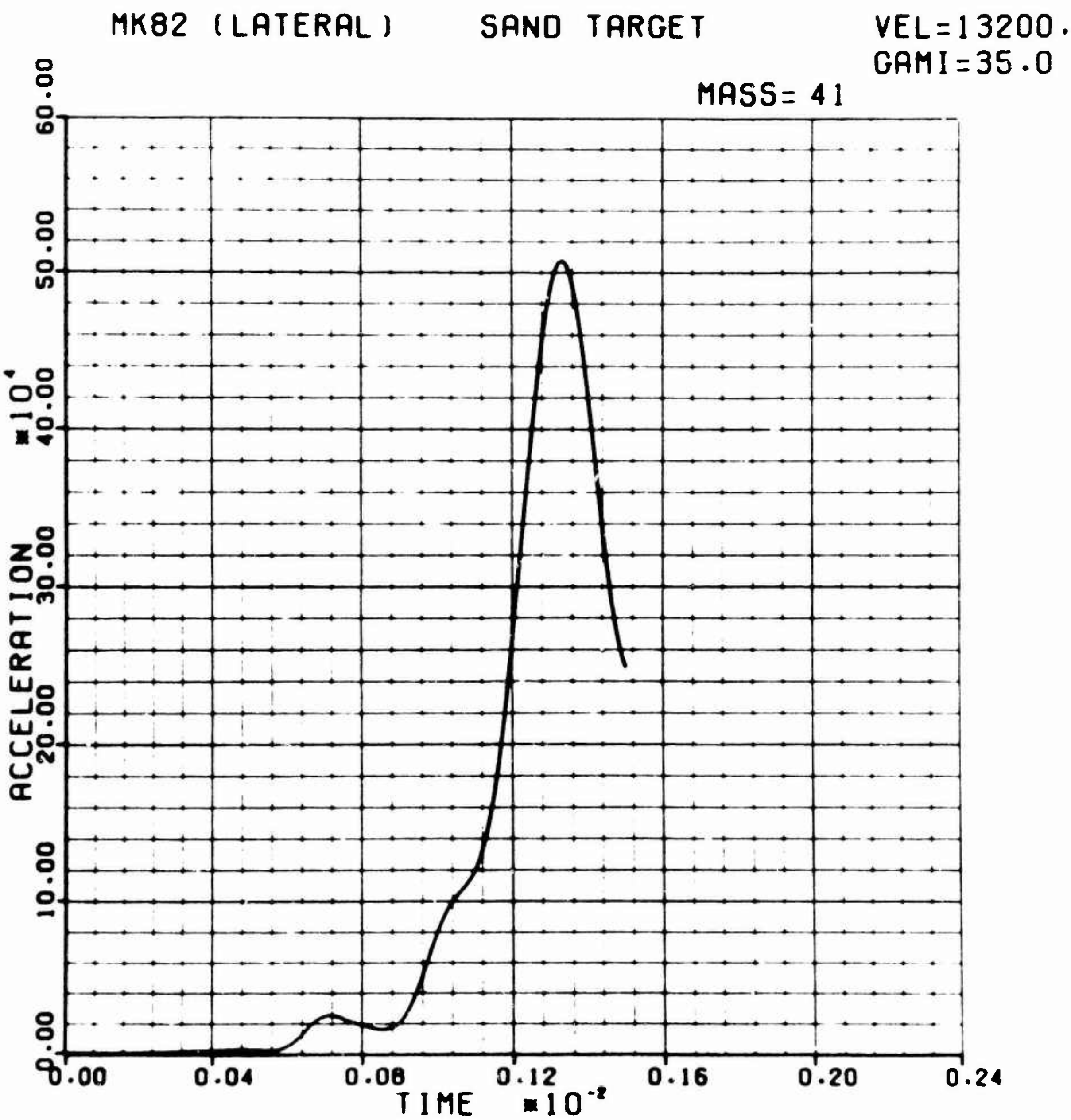

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=45.0
MASS= 43
120.00
80.00
40.00
-0.00
-40.00
-80.00
-120.00
ACCELERATION $*10^4$
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$

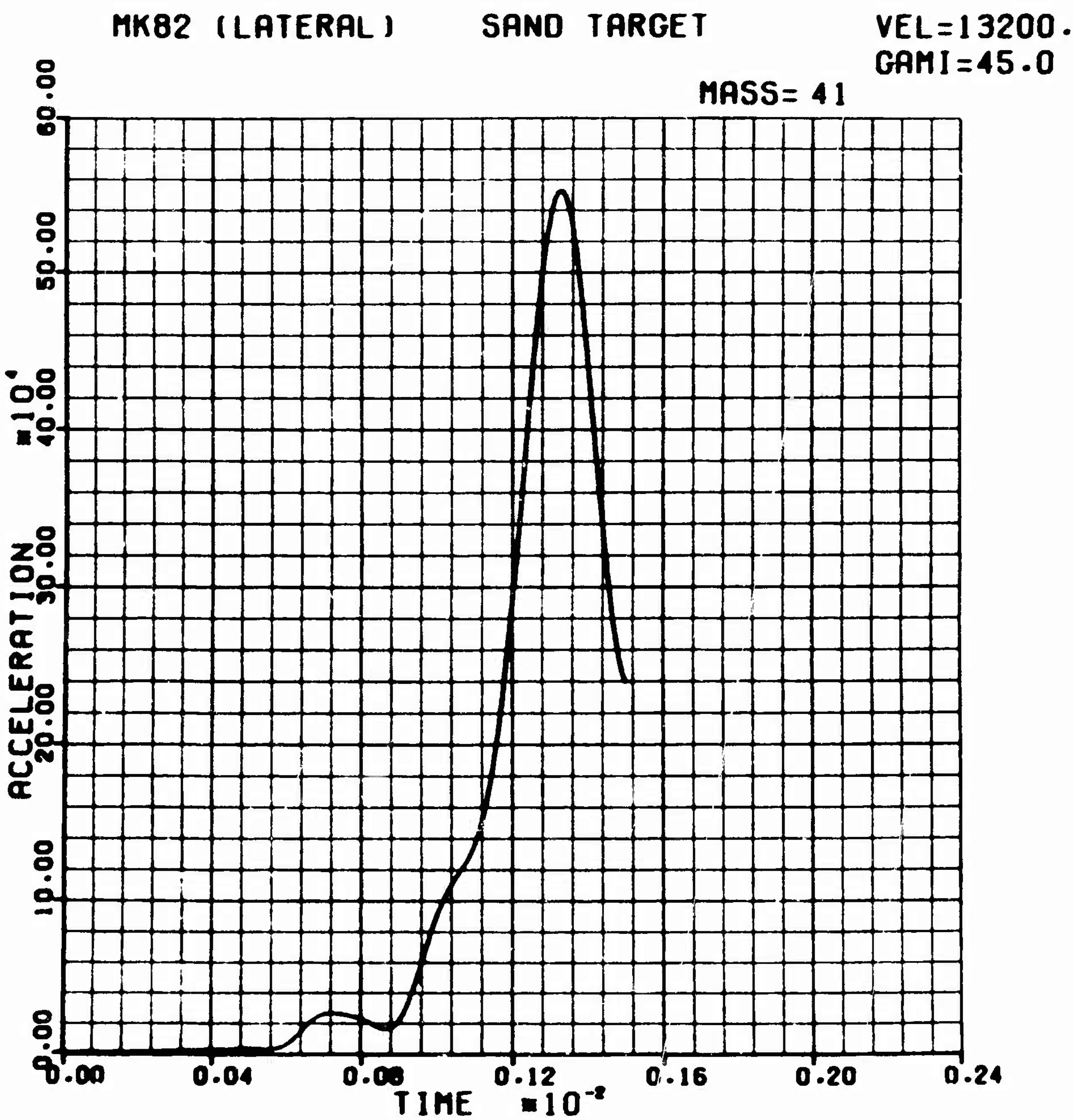

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 43
ACCELERATION *10^4
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2


MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 43
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
ACCELERATION *10⁴
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

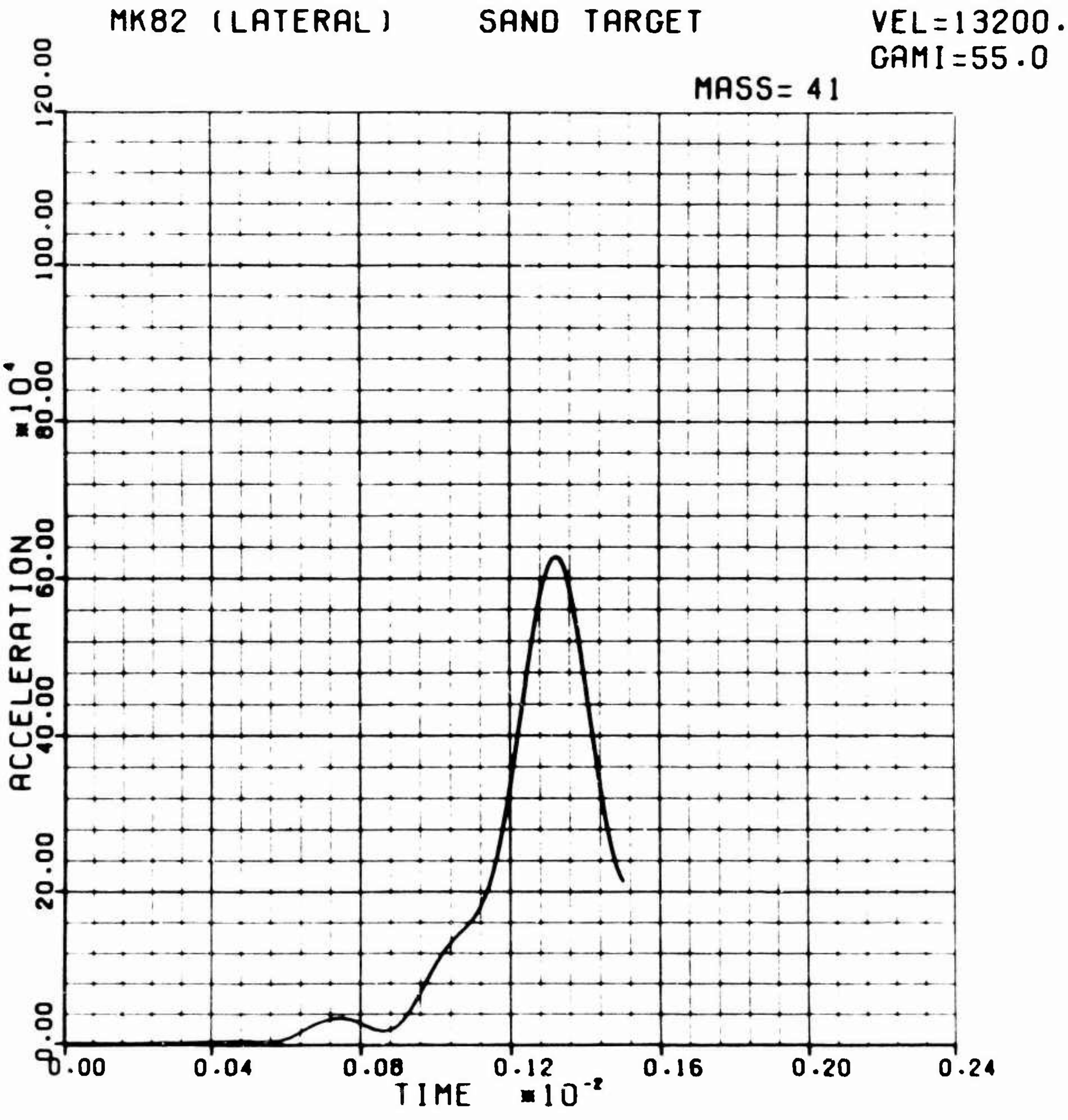

500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 43
ACCELERATION *10^4
100.00
50.00
-0.00
-50.00
-100.00
-150.00
-200.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2


MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 41
ACCELERATION ×10³
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME ×10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

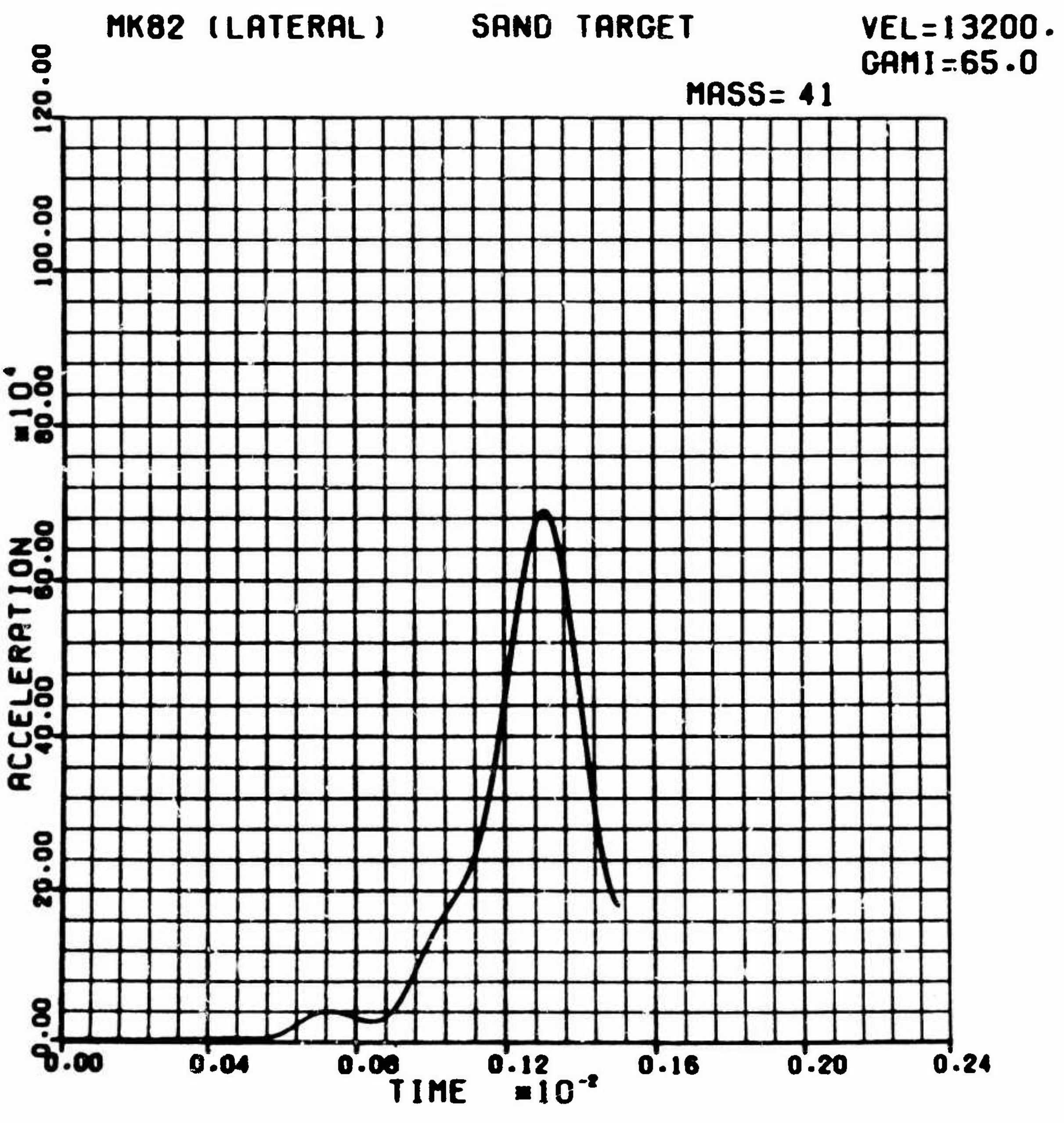

MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=35.0
MASS= 41
ACCELERATION *10⁴
0.00
10.00
20.00
30.00
40.00
50.00
60.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



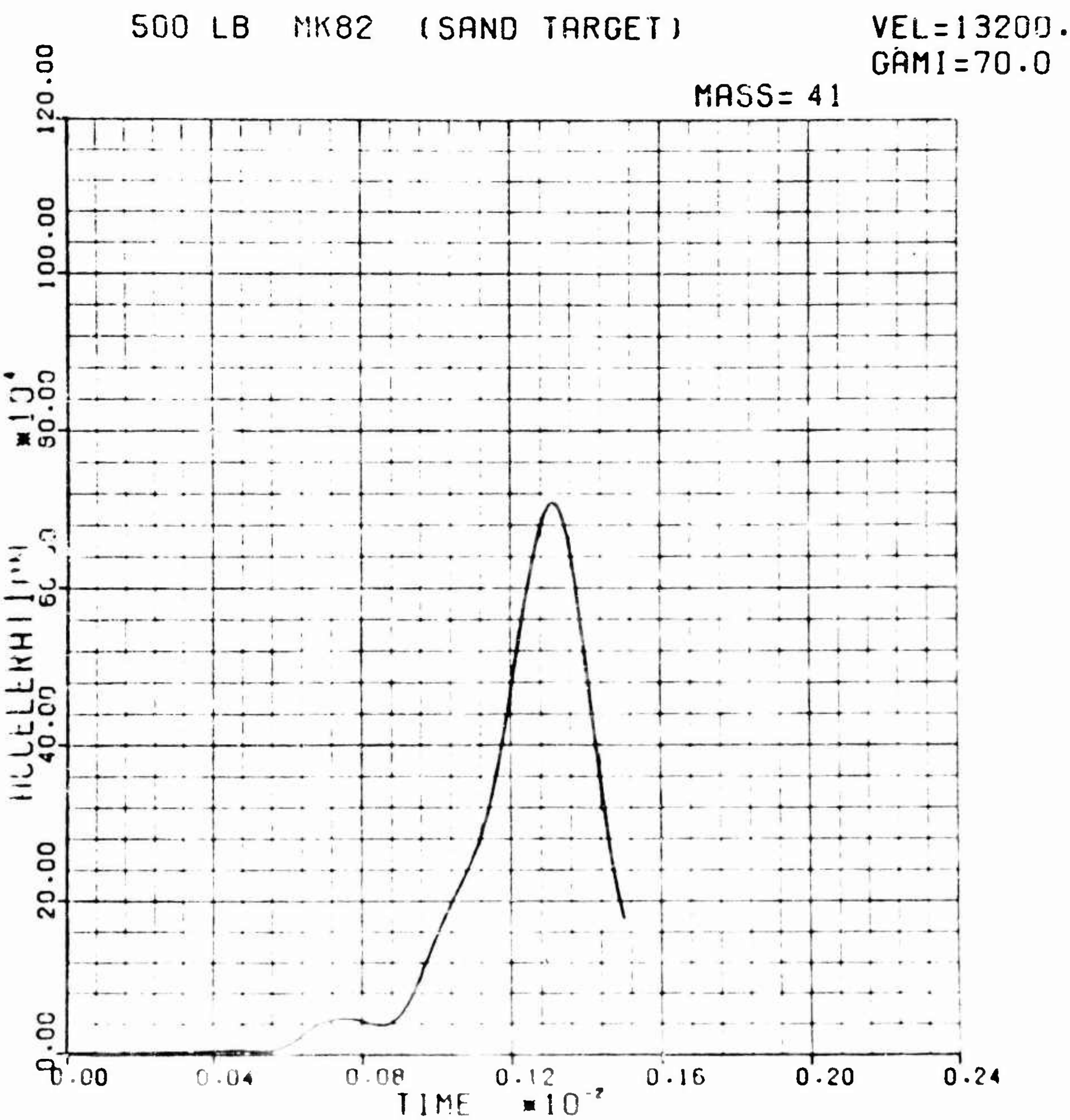
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=45.0
MASS= 41
ACCELERATION *10^4
0.00
10.00
20.00
30.00
40.00
50.00
60.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

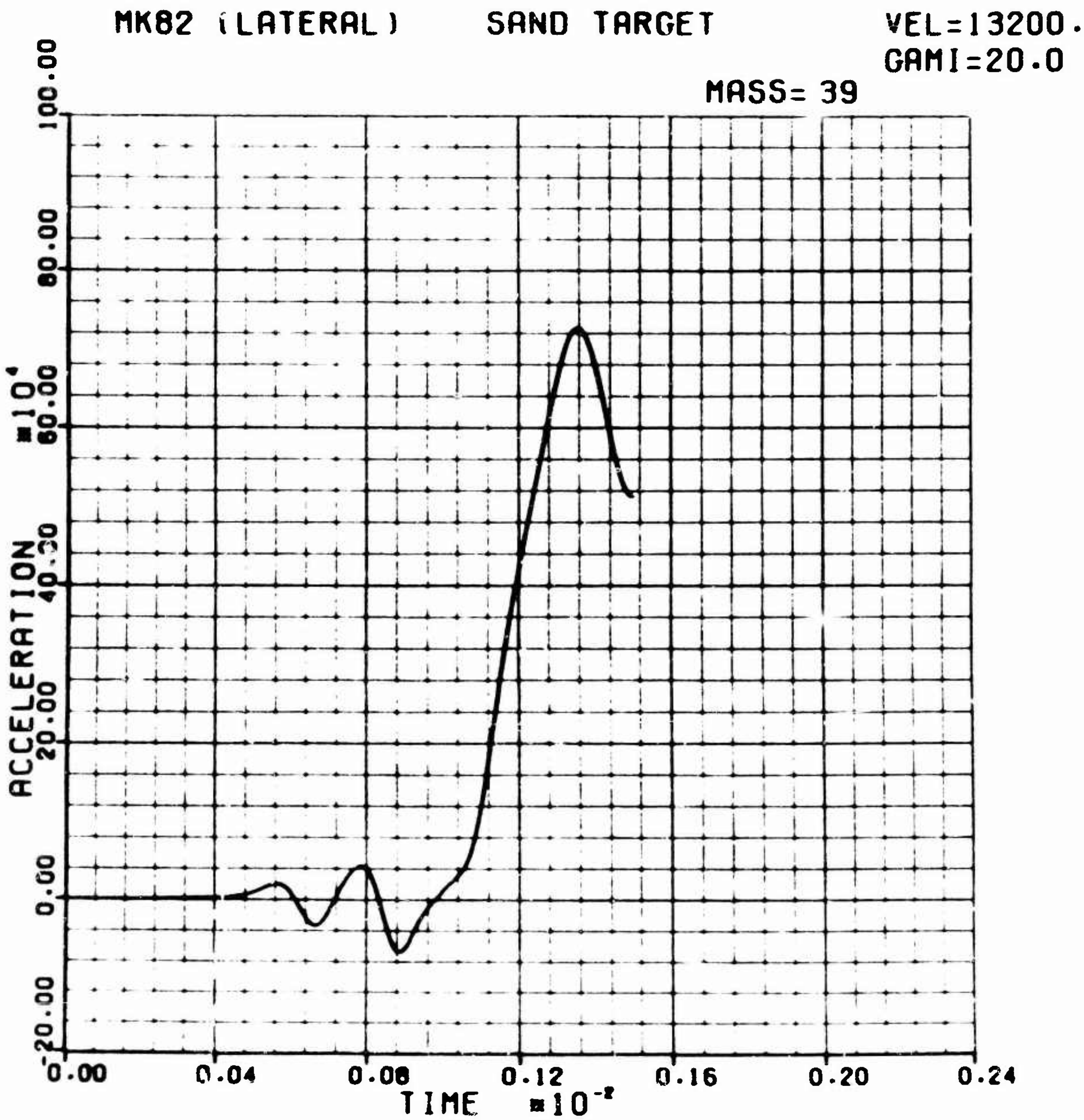


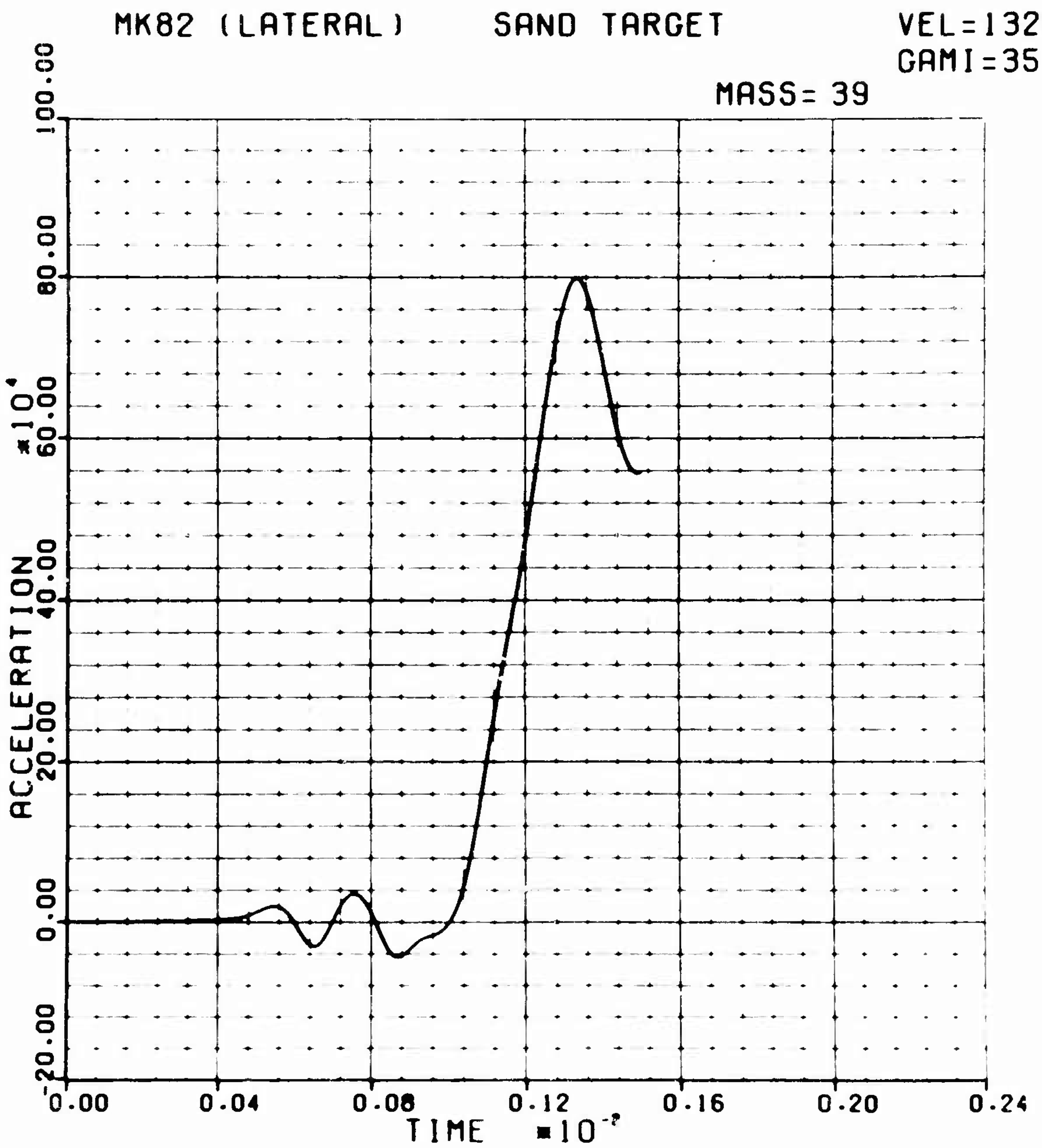
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 41
ACCELERATION ×10⁴
0.00
20.00
40.00
60.00
80.00
100.00
120.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²



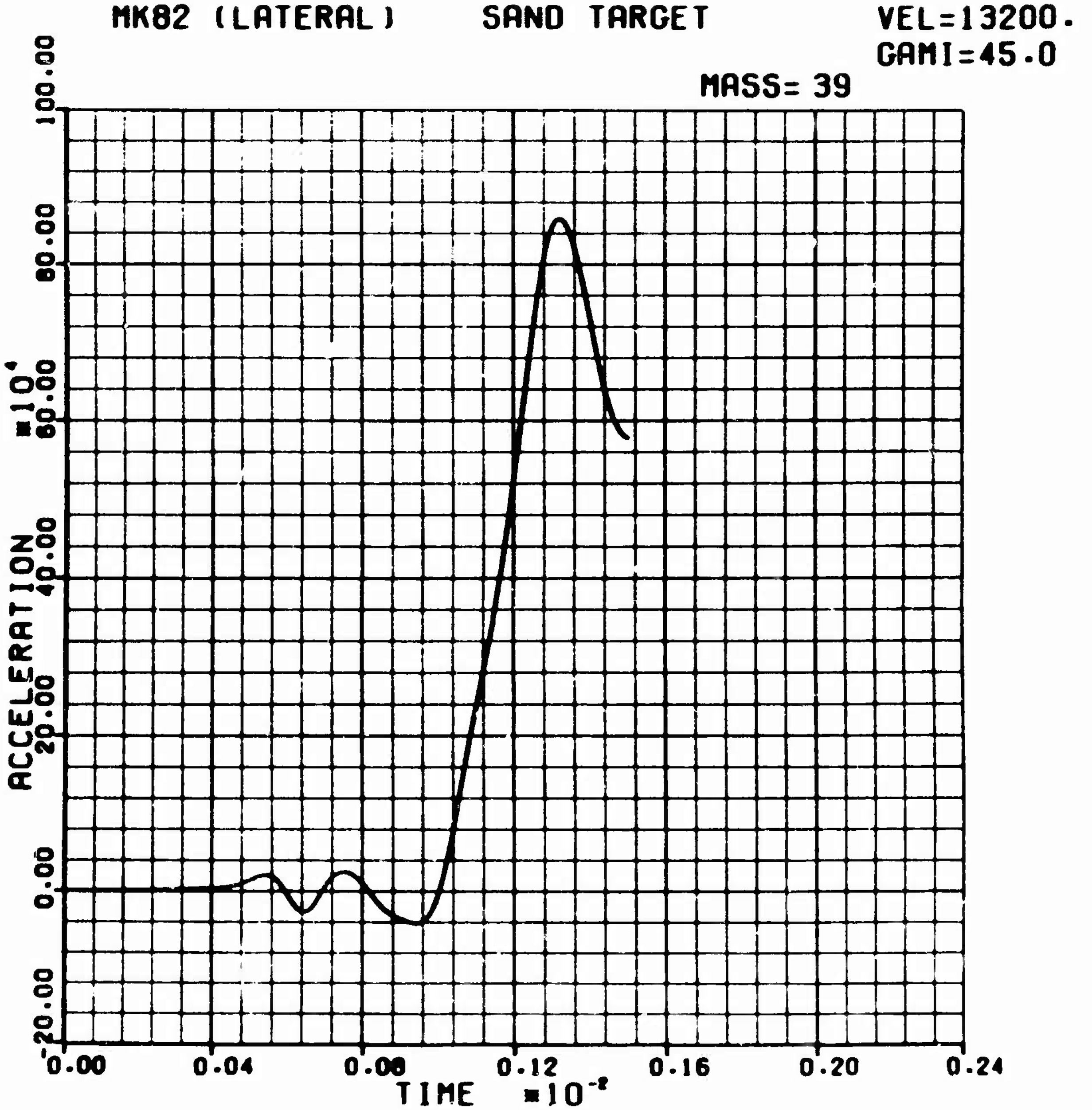
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 41
ACCELERATION *10^4
0.00
20.00
40.00
60.00
80.00
100.00
120.00
TIME *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24

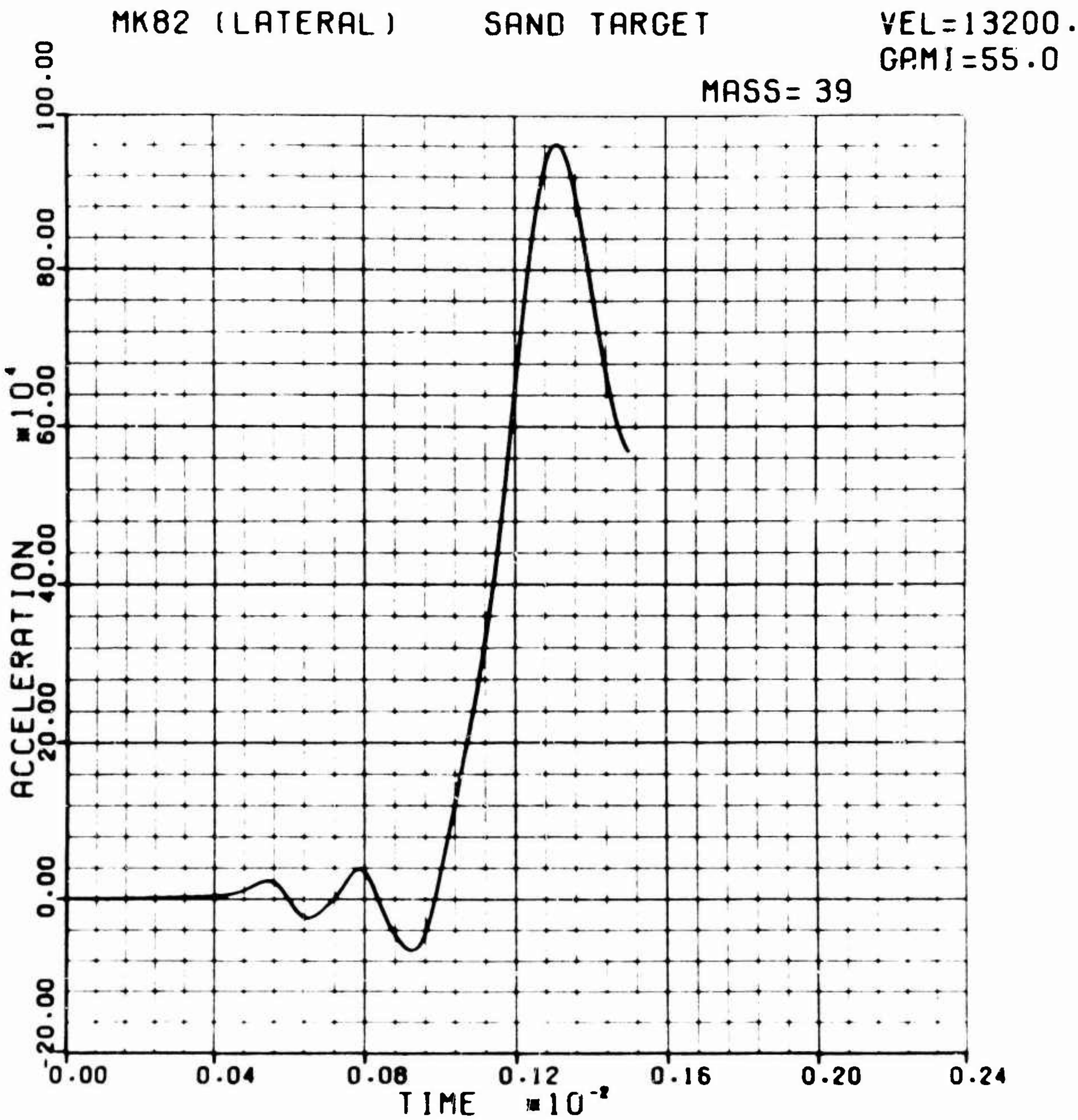

500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 41
0.00
20.00
40.00
60.00
80.00
100.00
120.00
ACCELERATION
*10⁴
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²


MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=20.0
MASS= 39
ACCELERATION $*10^4$
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$

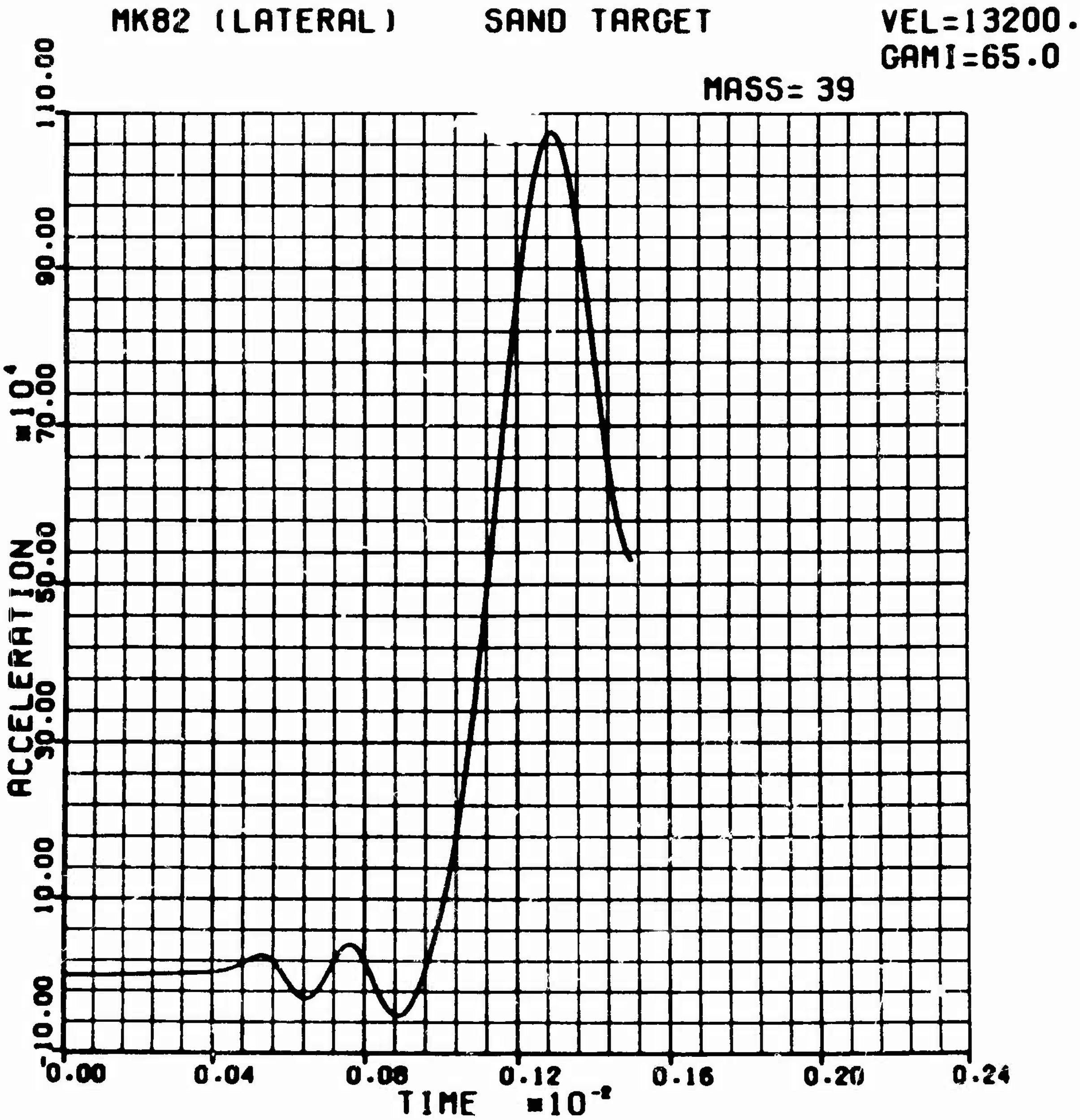


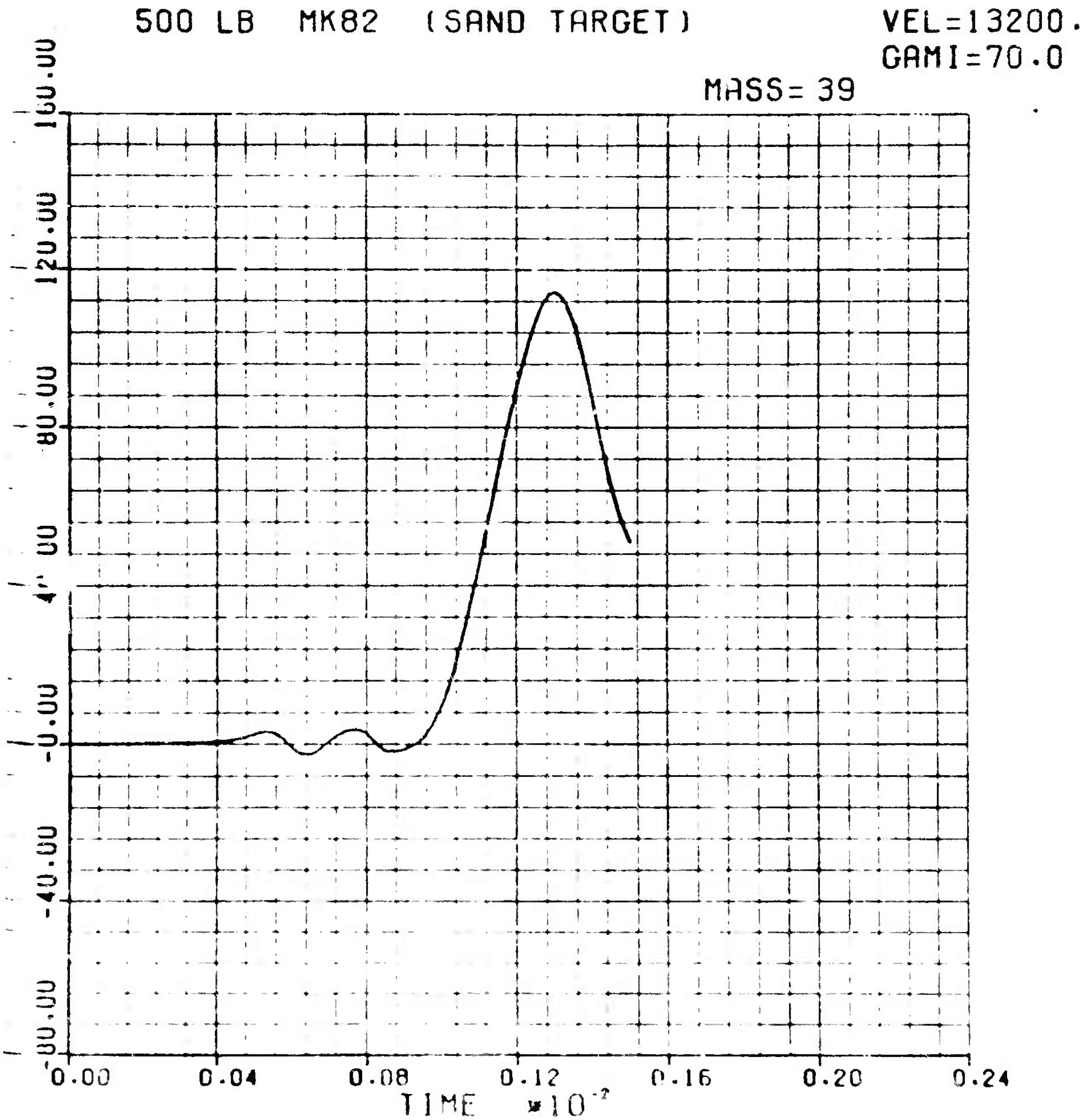
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=35.0
MASS= 39
ACCELERATION $*10^4$
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$


MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=45.0
MASS= 39
ACCELERATION *10⁴
TIME *10⁻²
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24

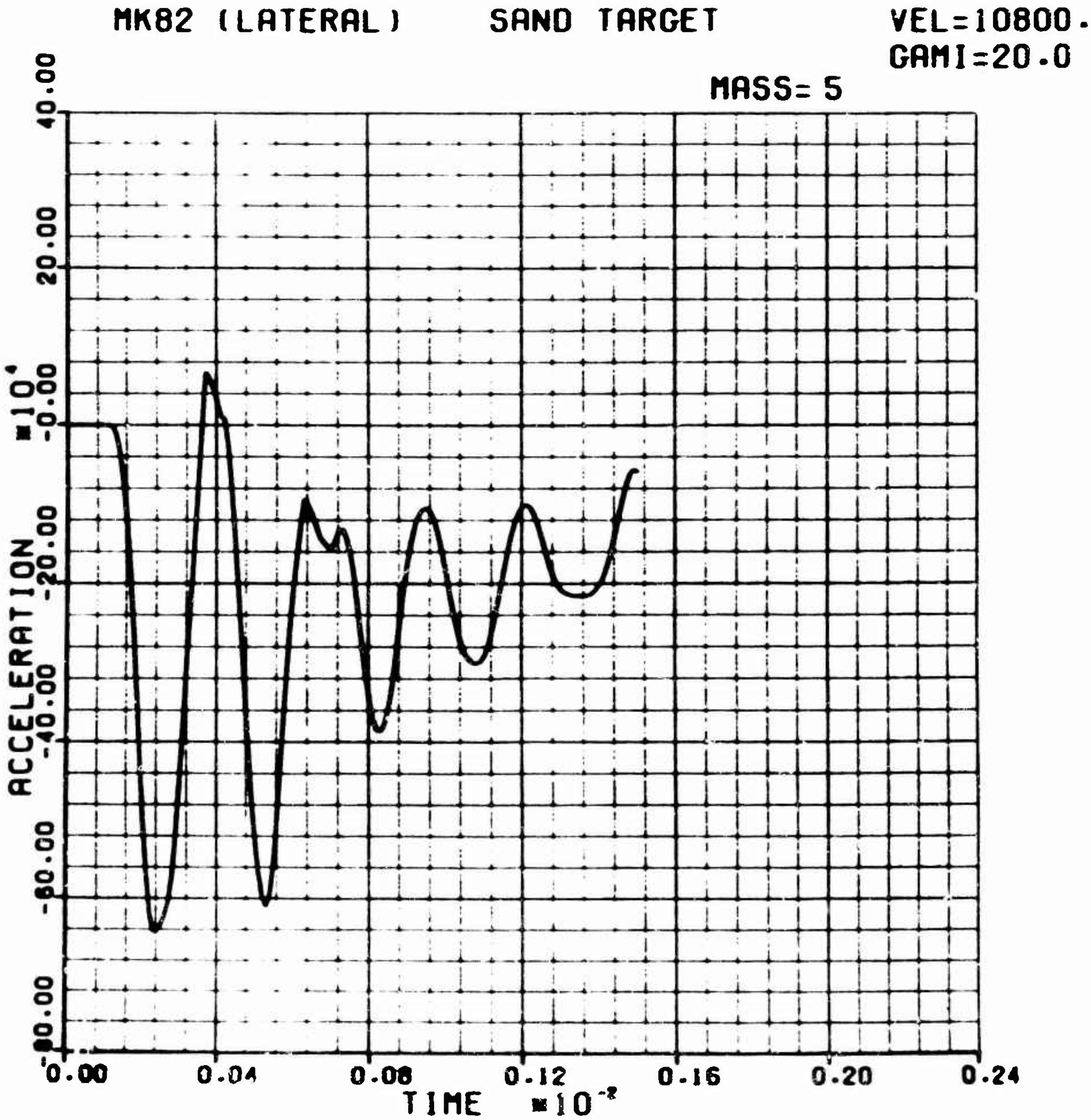


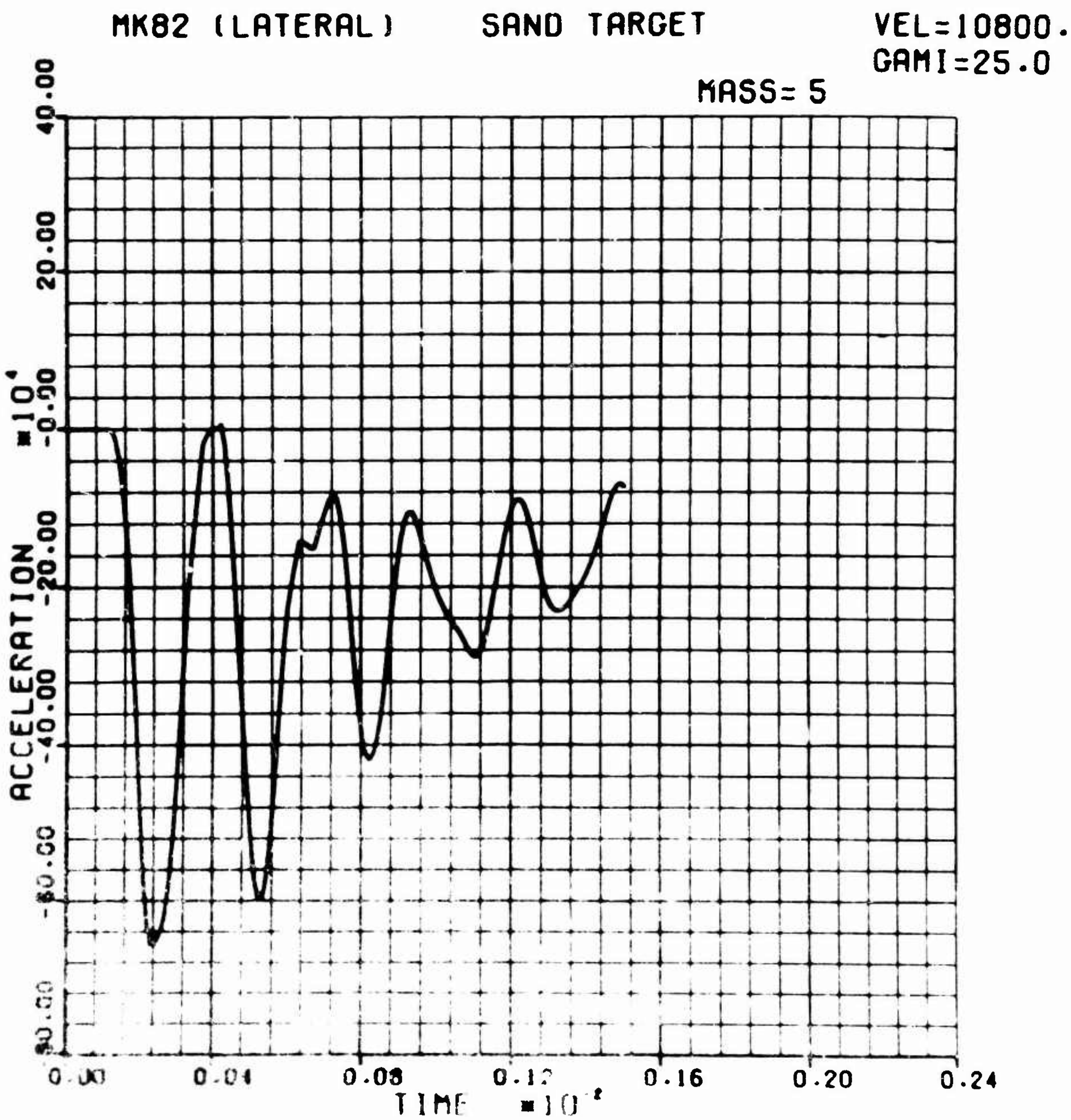
MK82 (LATERAL)
SAND TARGET
VEL=13200.
GAMI=55.0
MASS= 39
ACCELERATION *10⁴
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

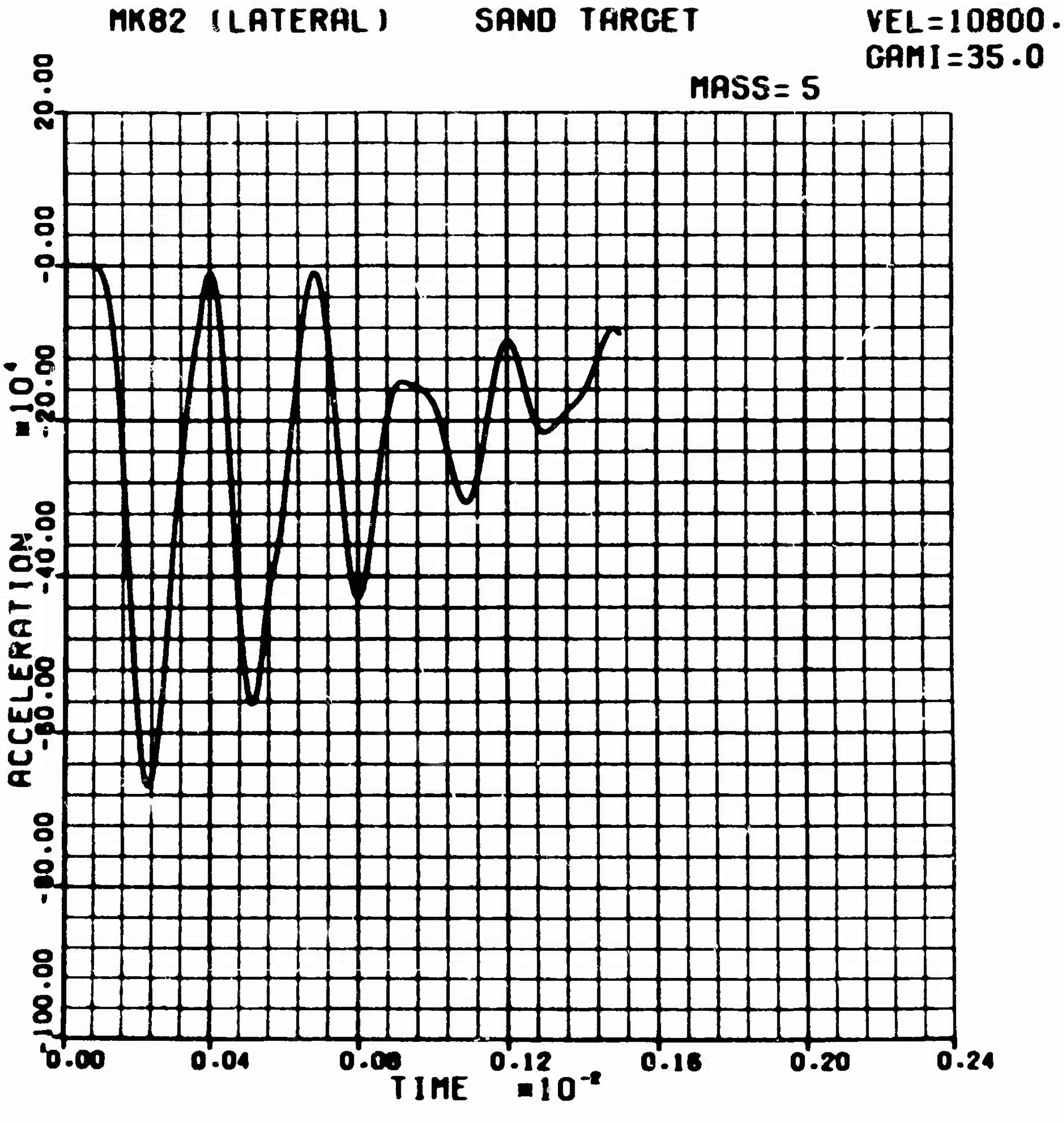

MK82 (LATERAL) SAND TARGET
VEL=13200.
GAMI=65.0
MASS= 39
ACCELERATION *10⁴
110.00
90.00
70.00
50.00
30.00
10.00
-10.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



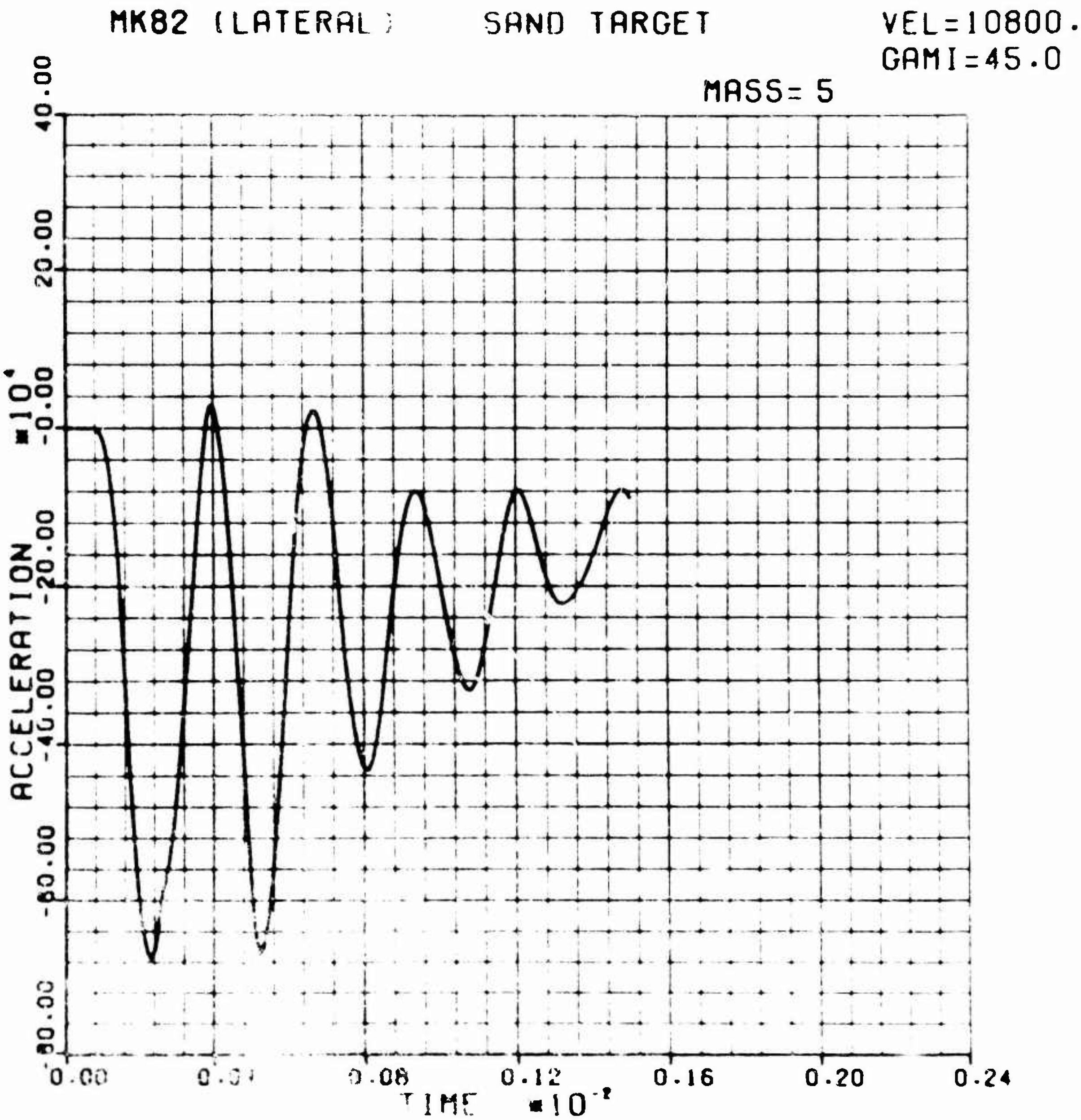
500 LB MK82 (SAND TARGET)
VEL=13200.
GAMI=70.0
MASS= 39
160.00
120.00
80.00
-0.00
-40.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=20.0
MASS= 5
ACCELERATION *10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

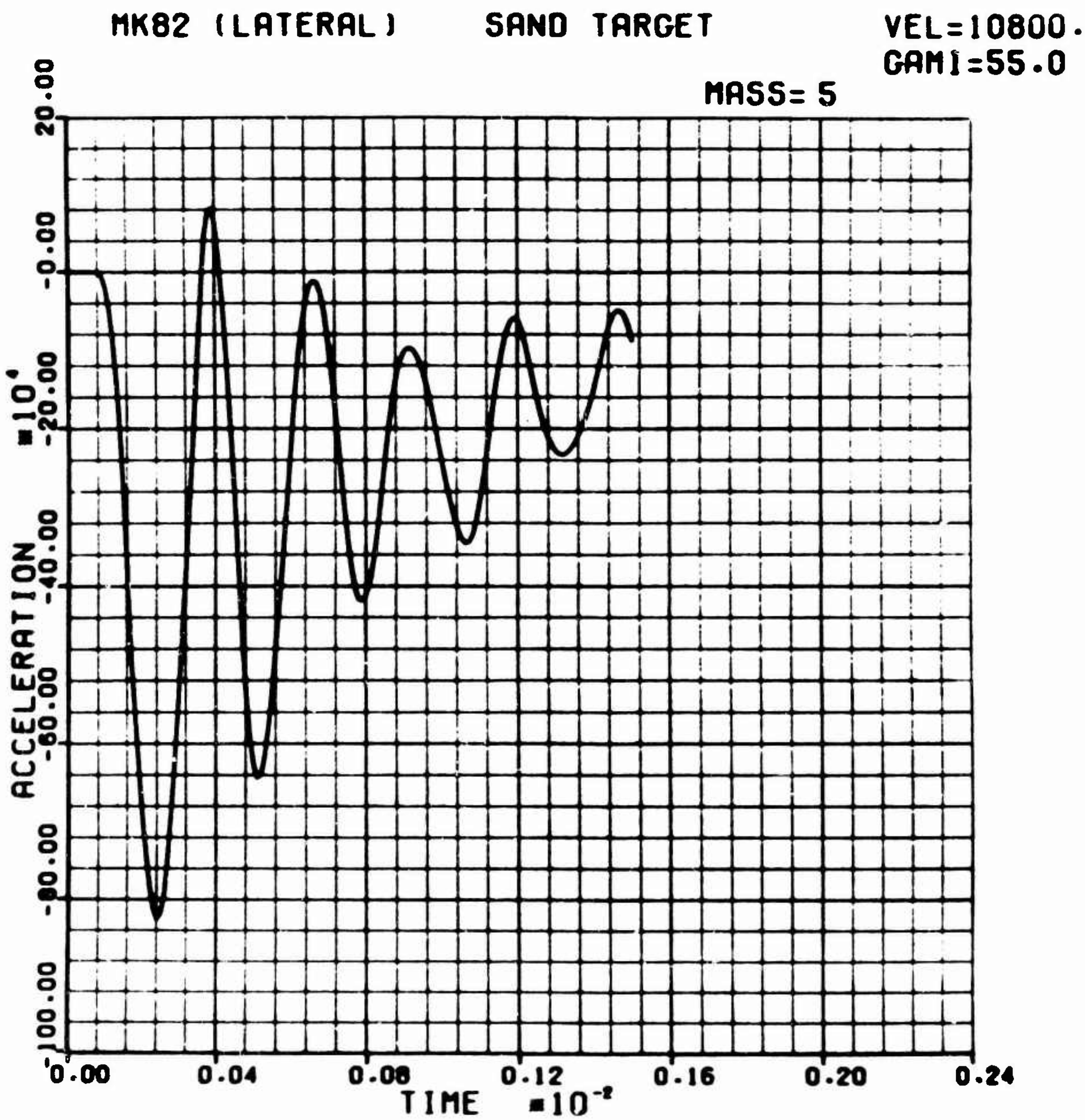

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=25.0
MASS= 5
ACCELERATION *10^4
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

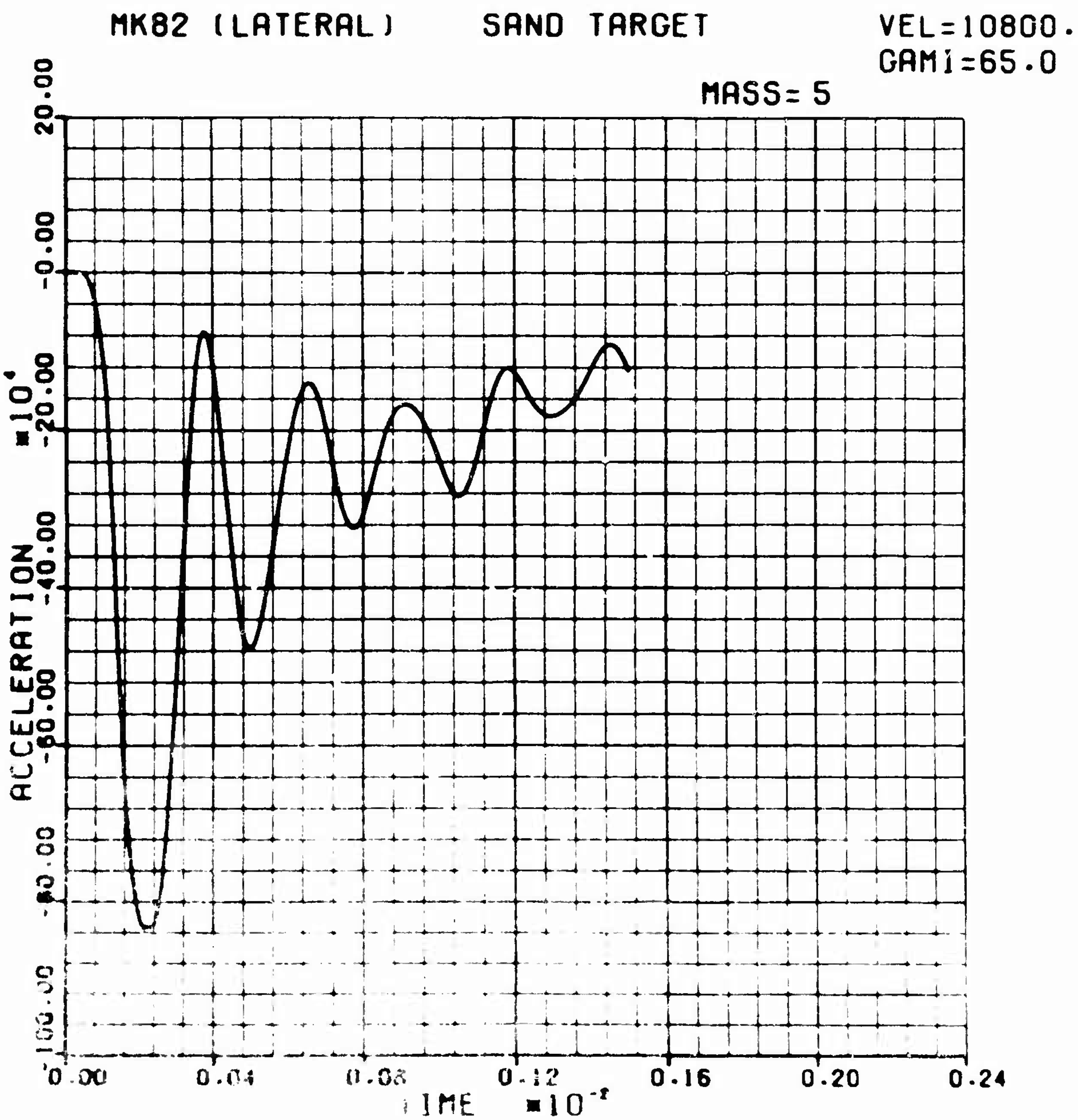


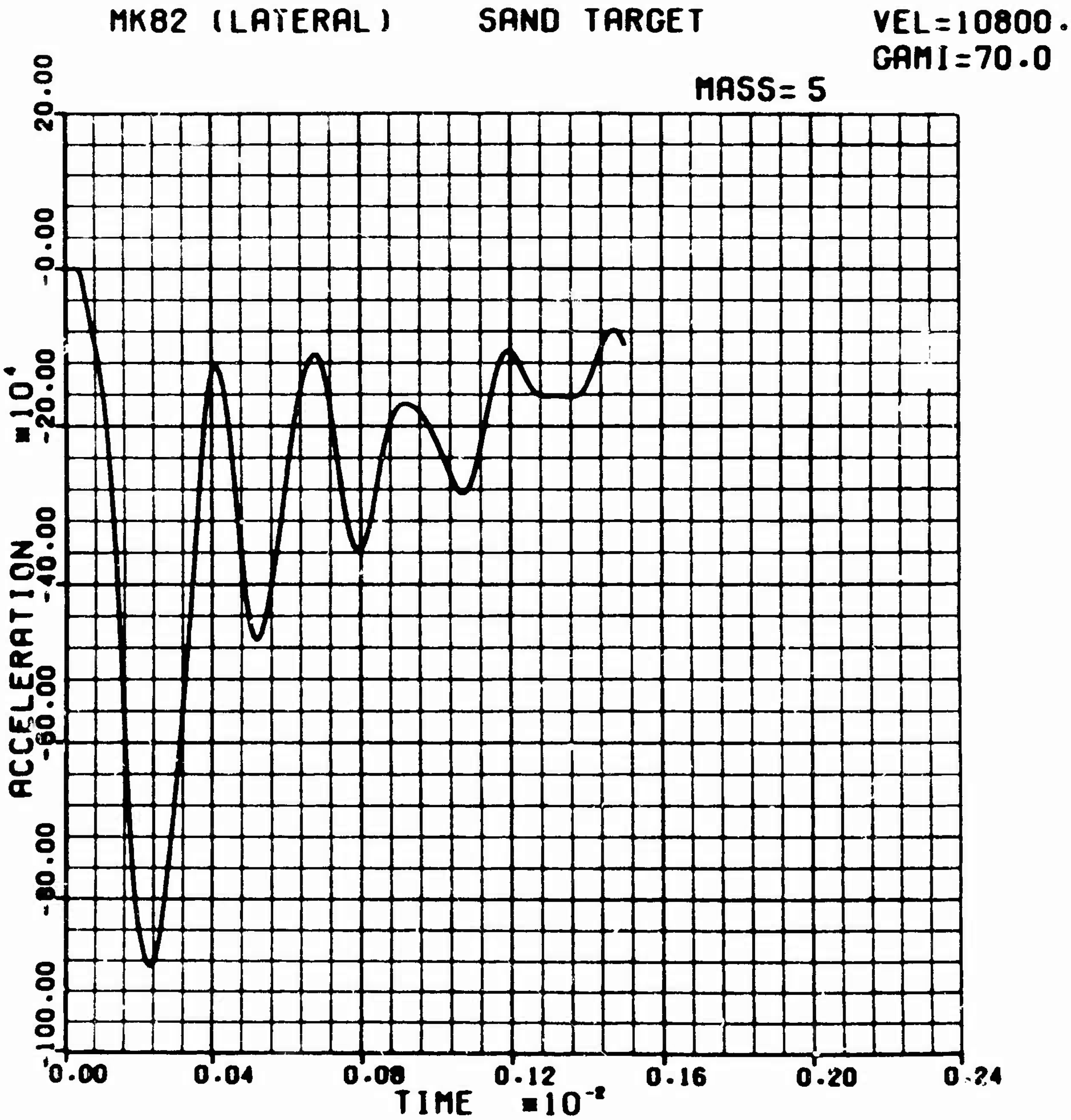
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 5
ACCELERATION *10^4
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
TIME *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24



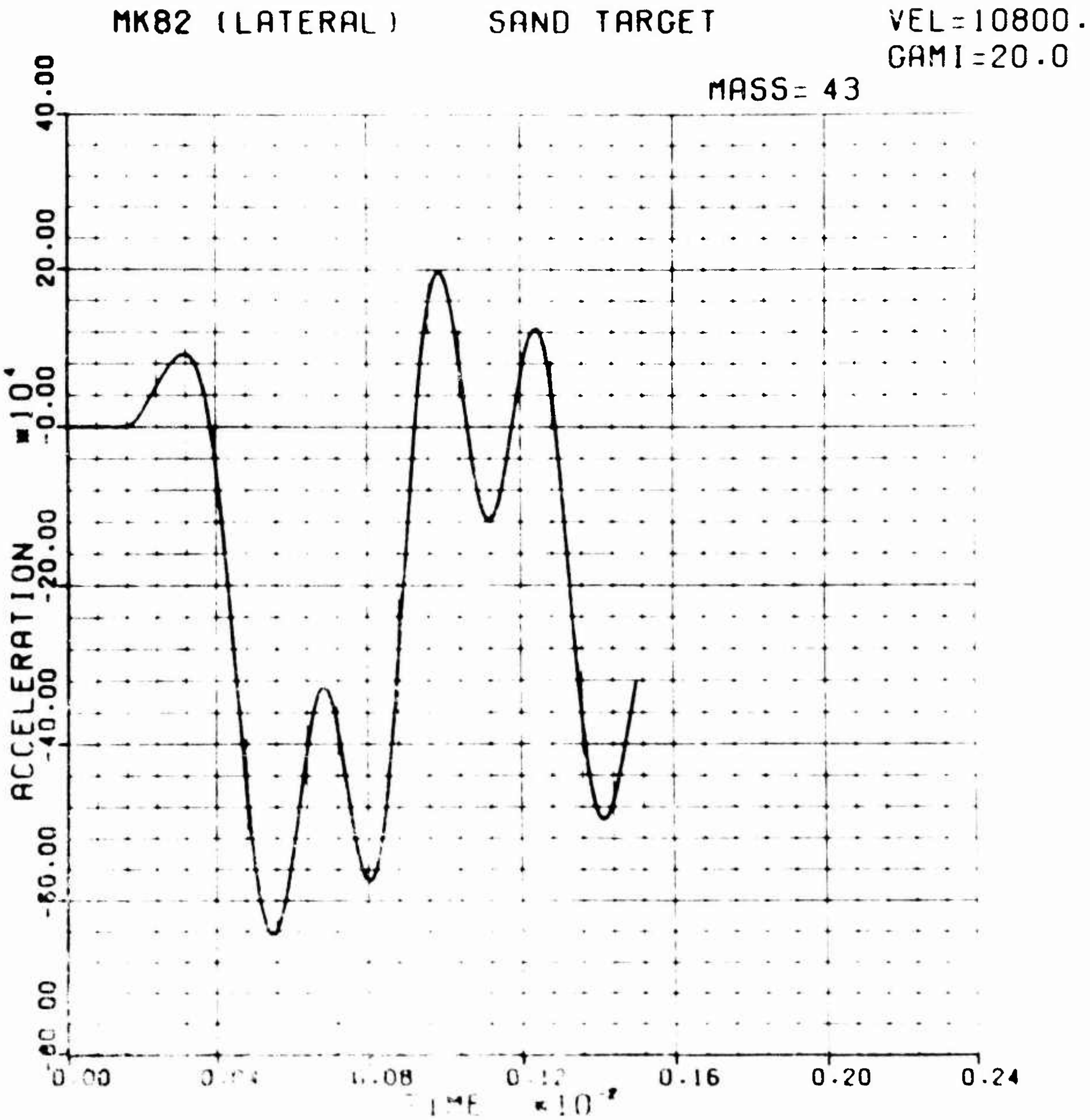
MK82 (LATERAL) SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 5
ACCELERATION *10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAM1=55.0
MASS= 5
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
ACCELERATION *10^4
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

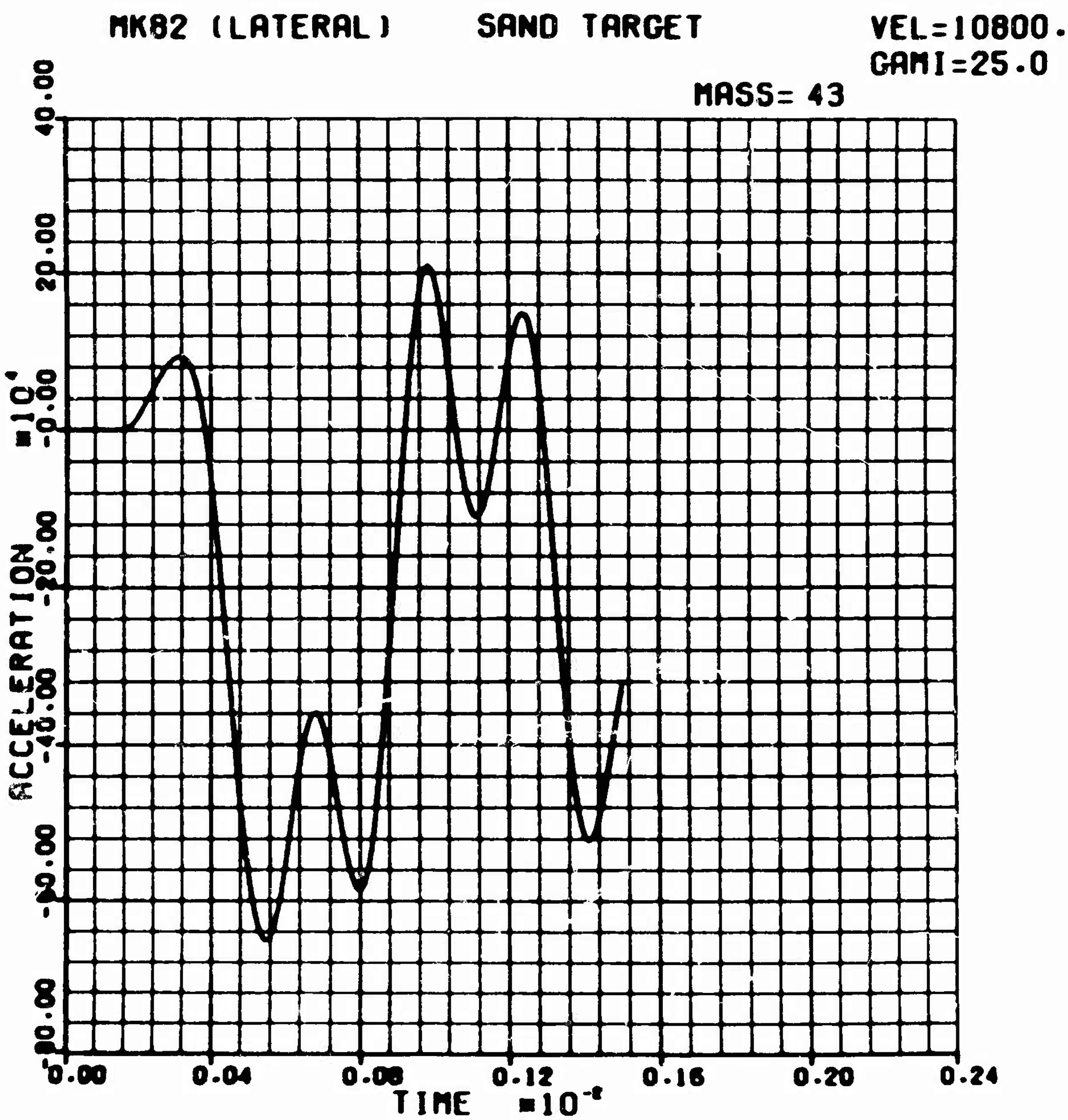

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 5
ACCELERATION *10⁴
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻¹

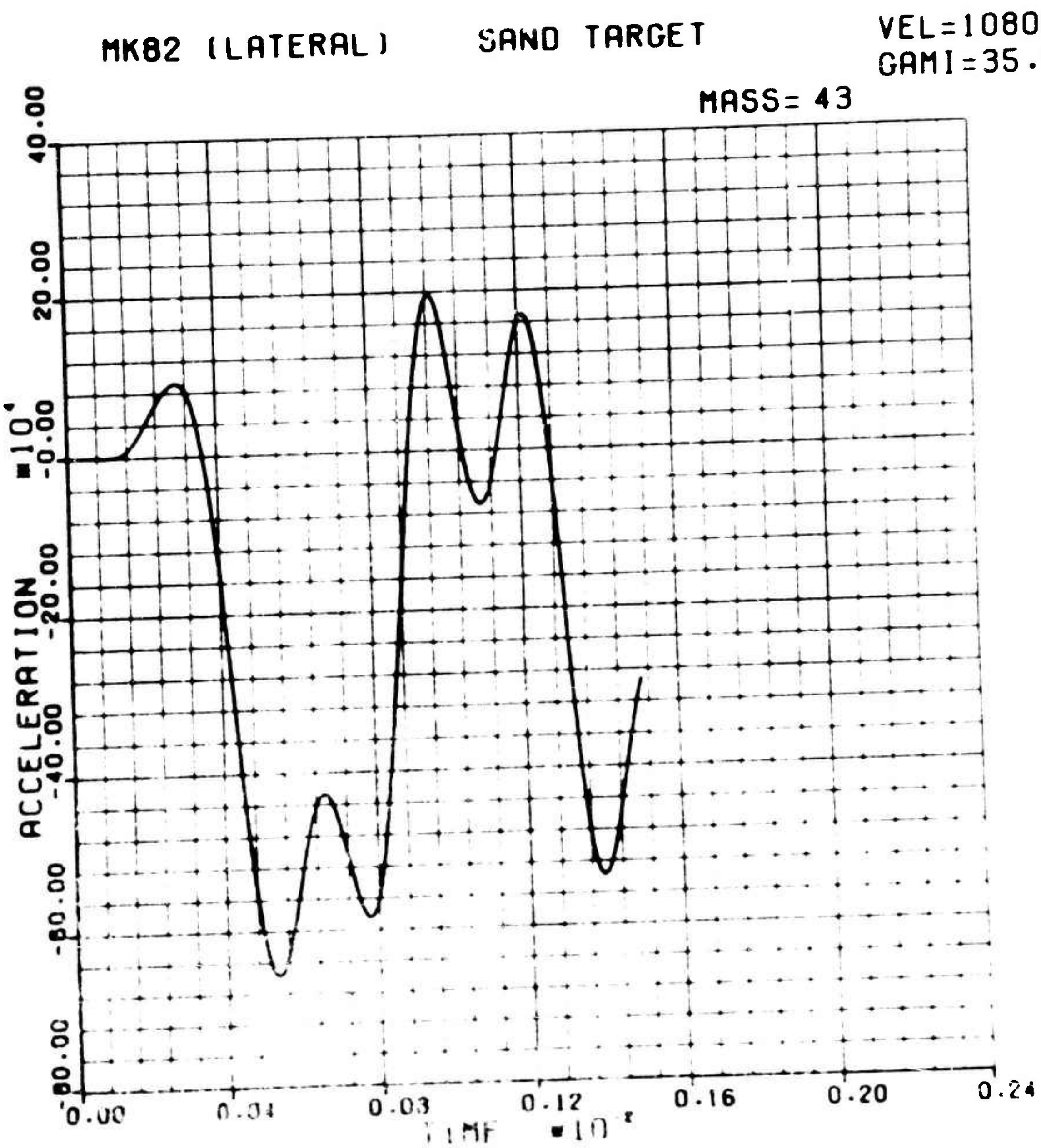


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=70.0
MASS= 5
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
-100.00
ACCELERATION *10⁴
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

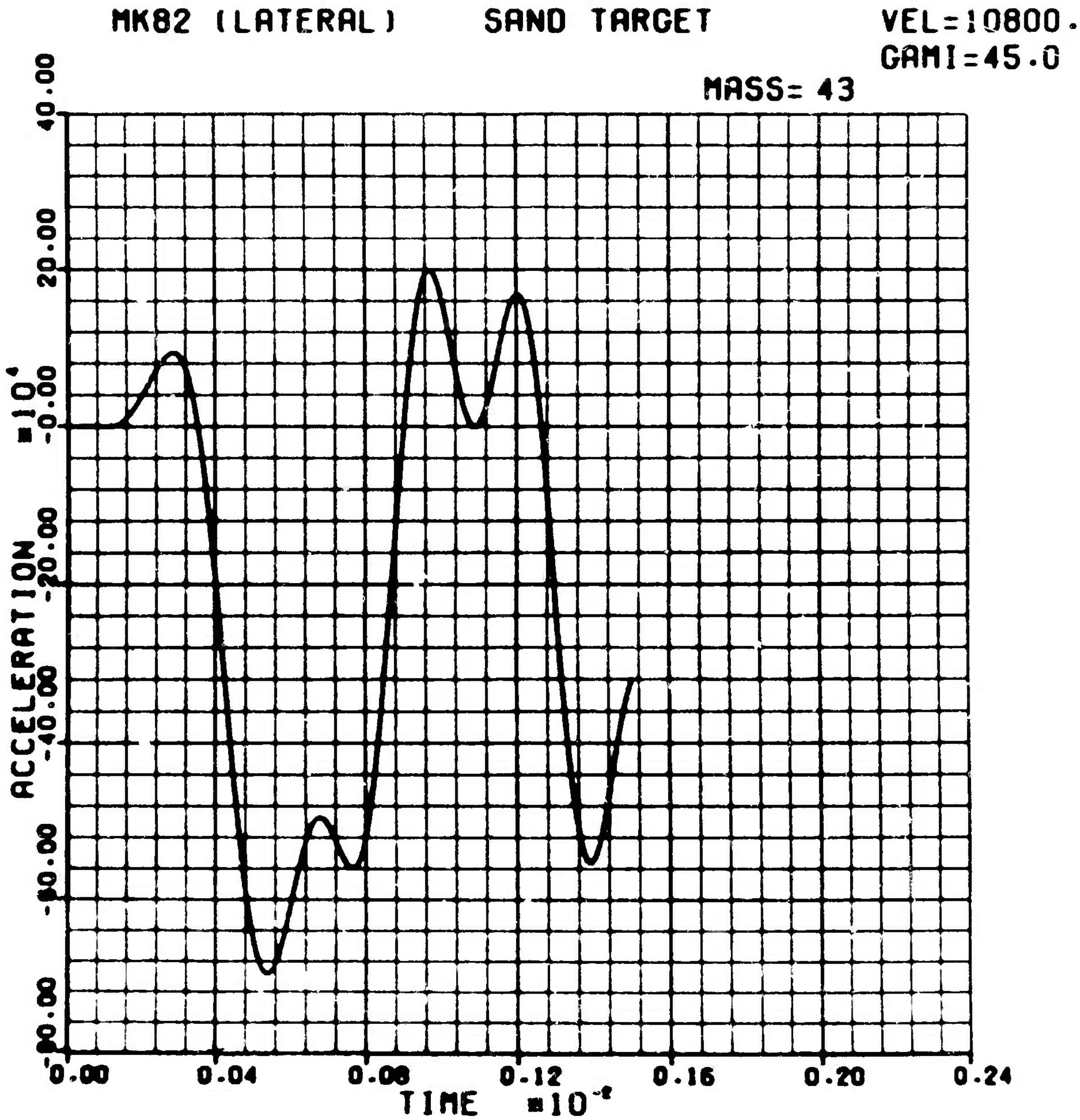


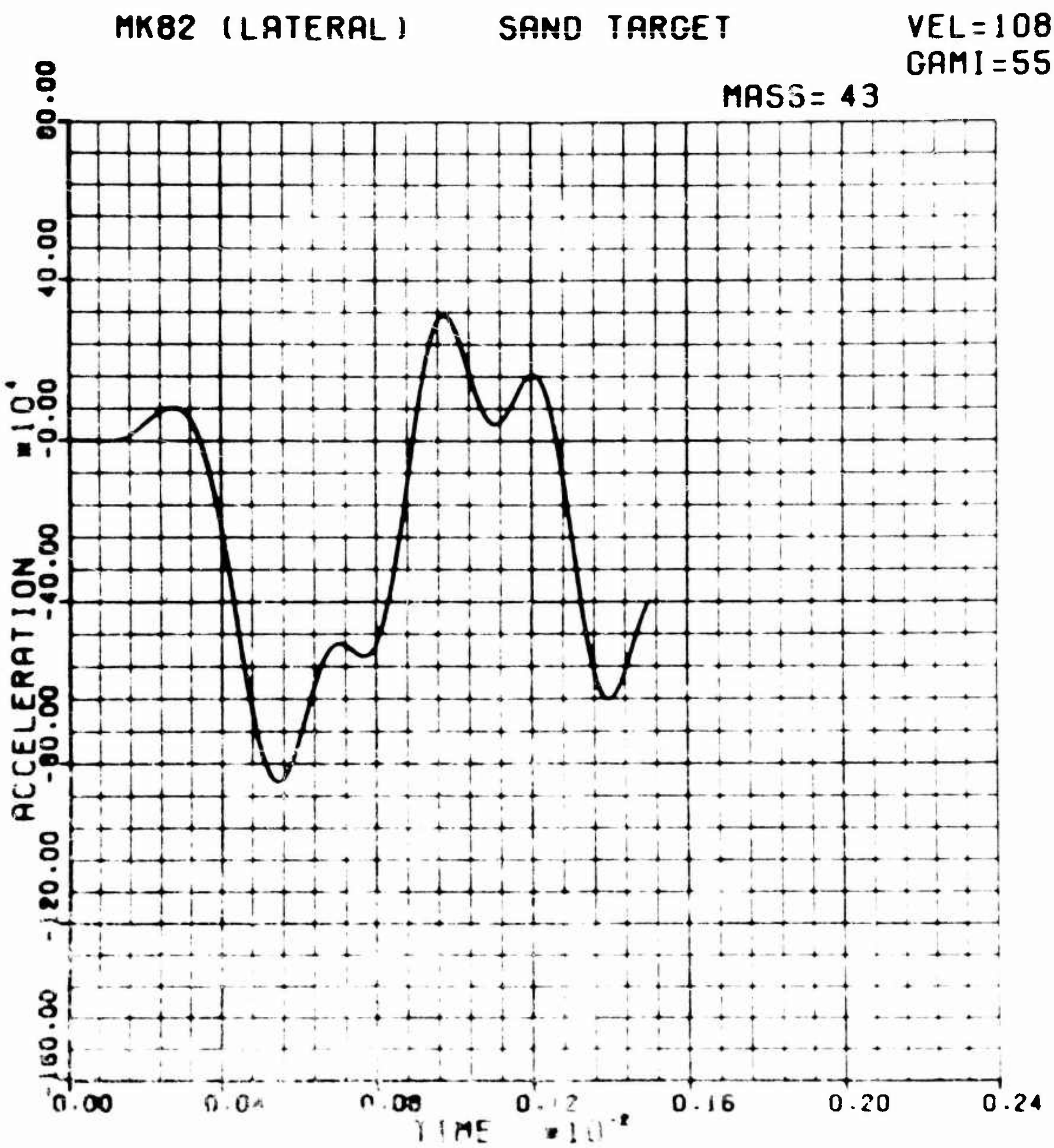
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=20.0
MASS= 43
ACCELERATION *10⁴
40.00
20.00
0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.08
0.16
0.20
0.24
TIME *10⁻²

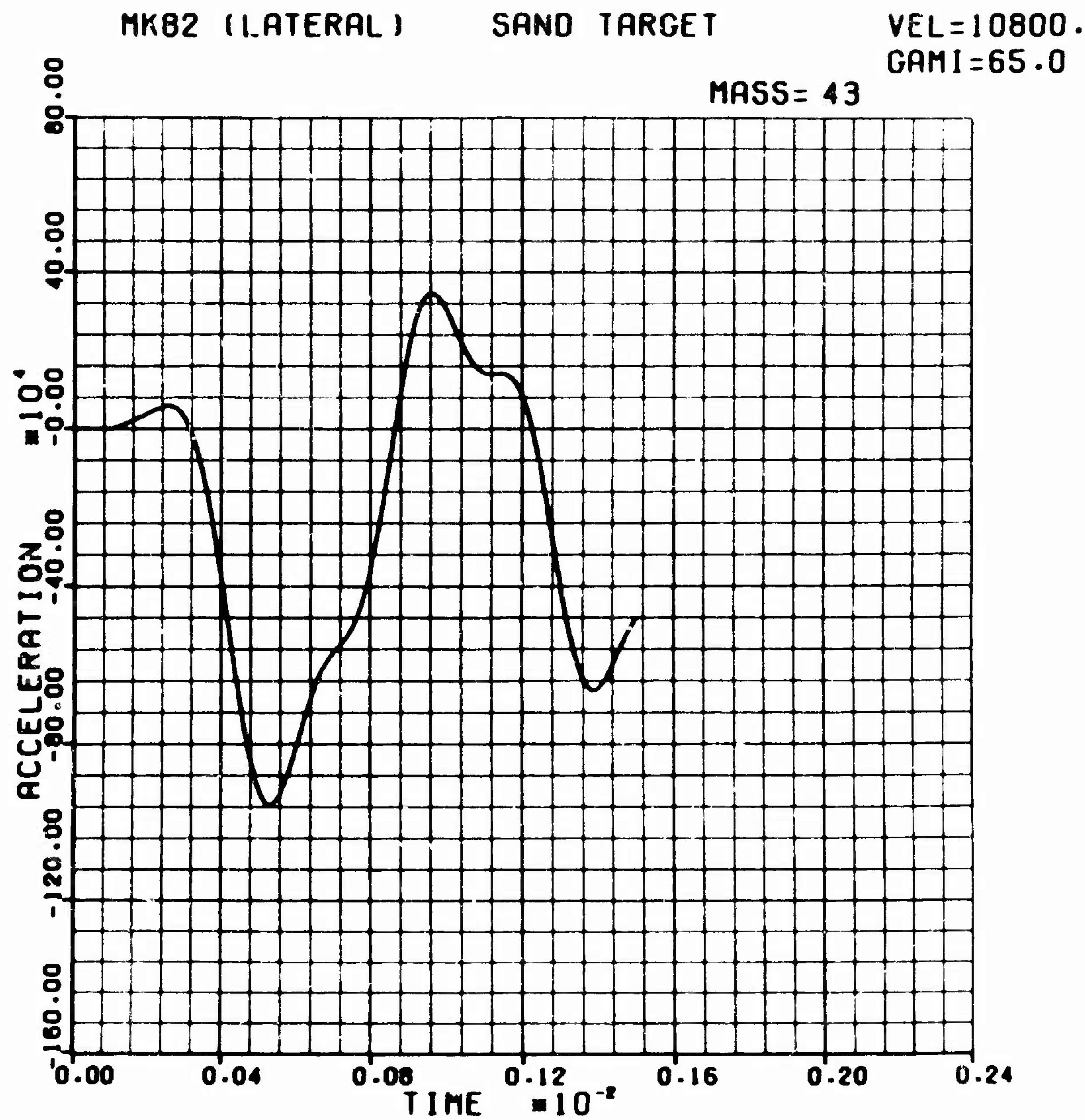

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=25.0
MASS= 43
ACCELERATION *10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

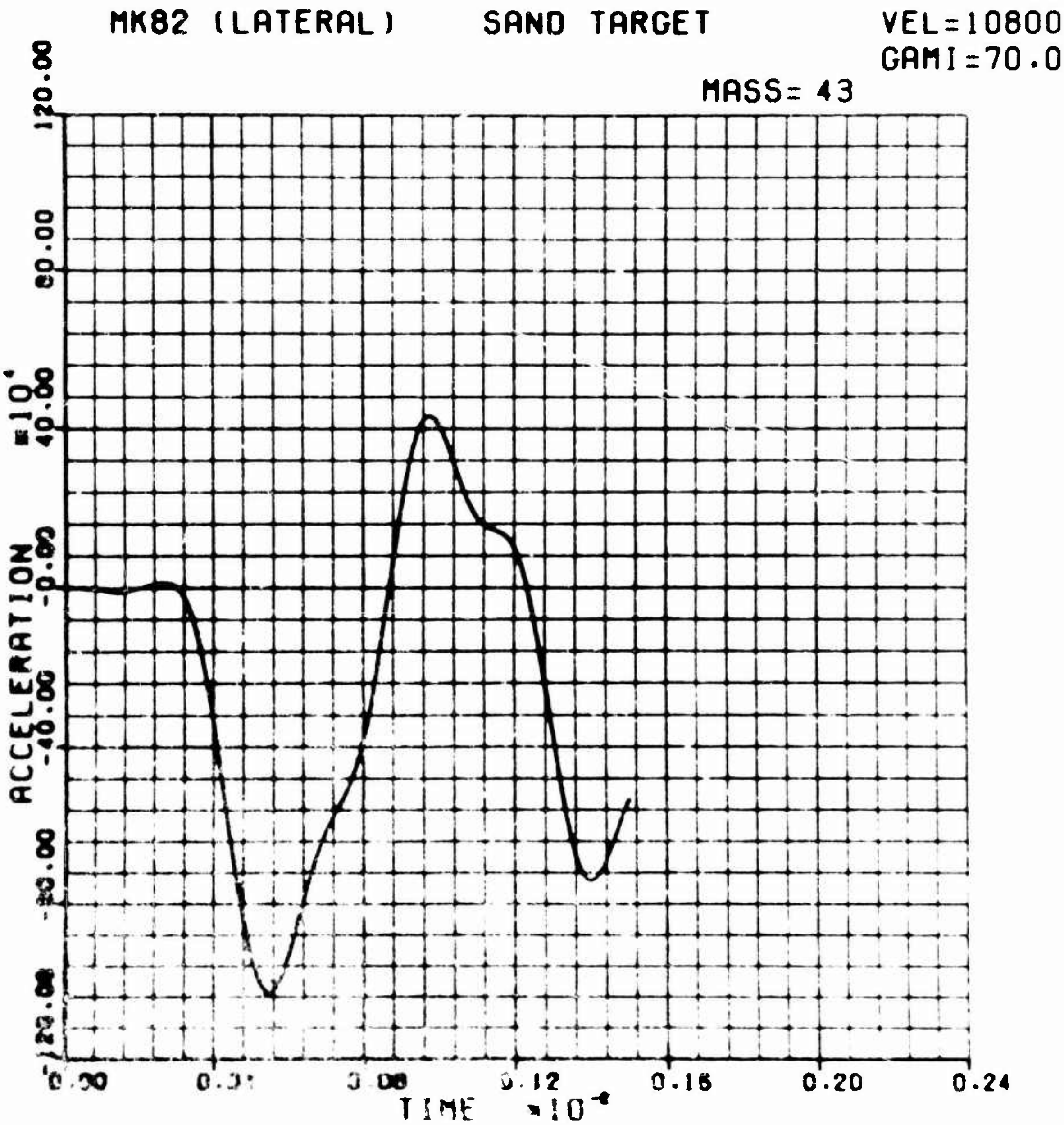


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 43
ACCELERATION *10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10

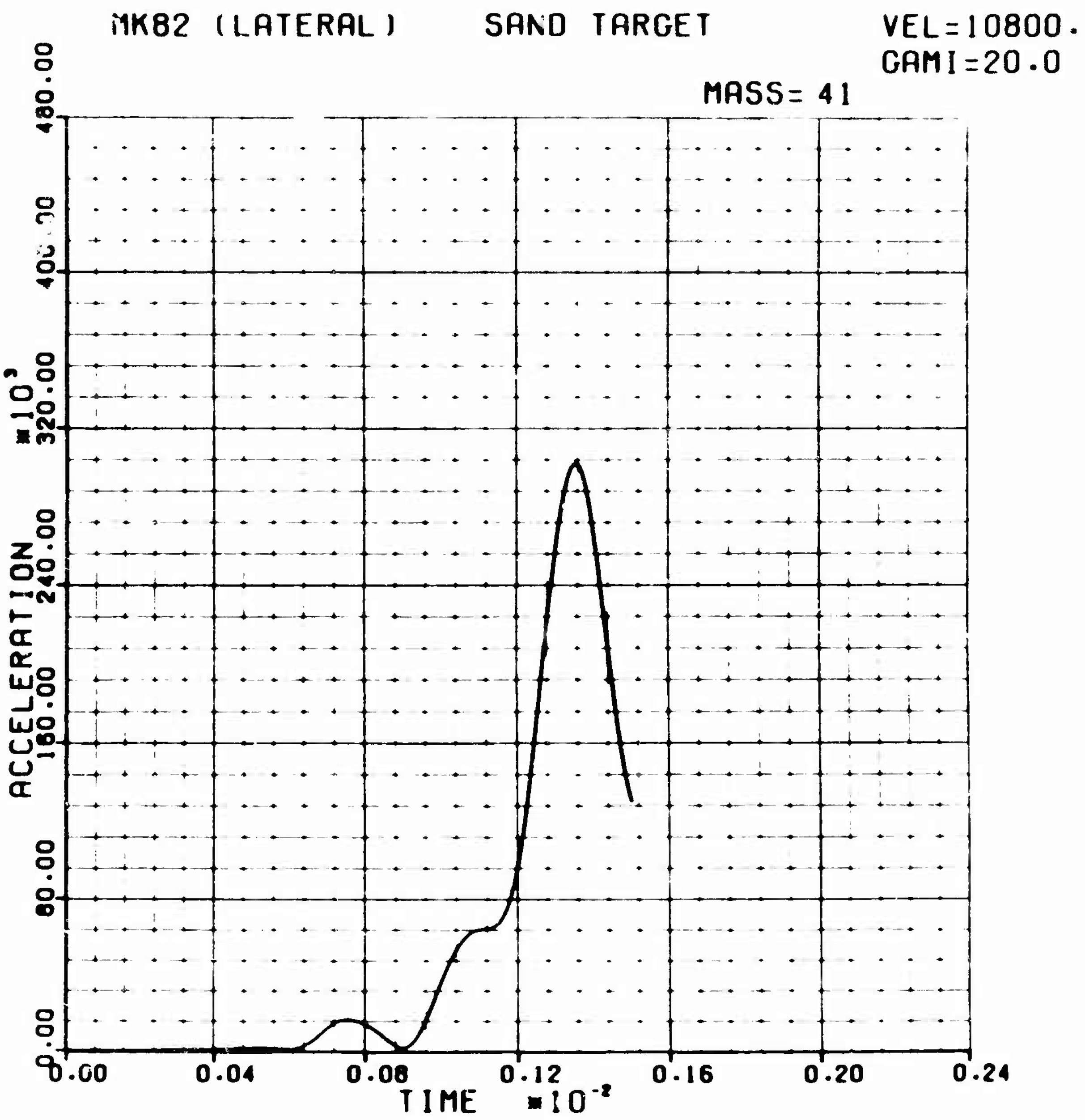

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 43
ACCELERATION
*10⁴
40.00
20.00
-0.00
-20.00
-40.00
-60.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

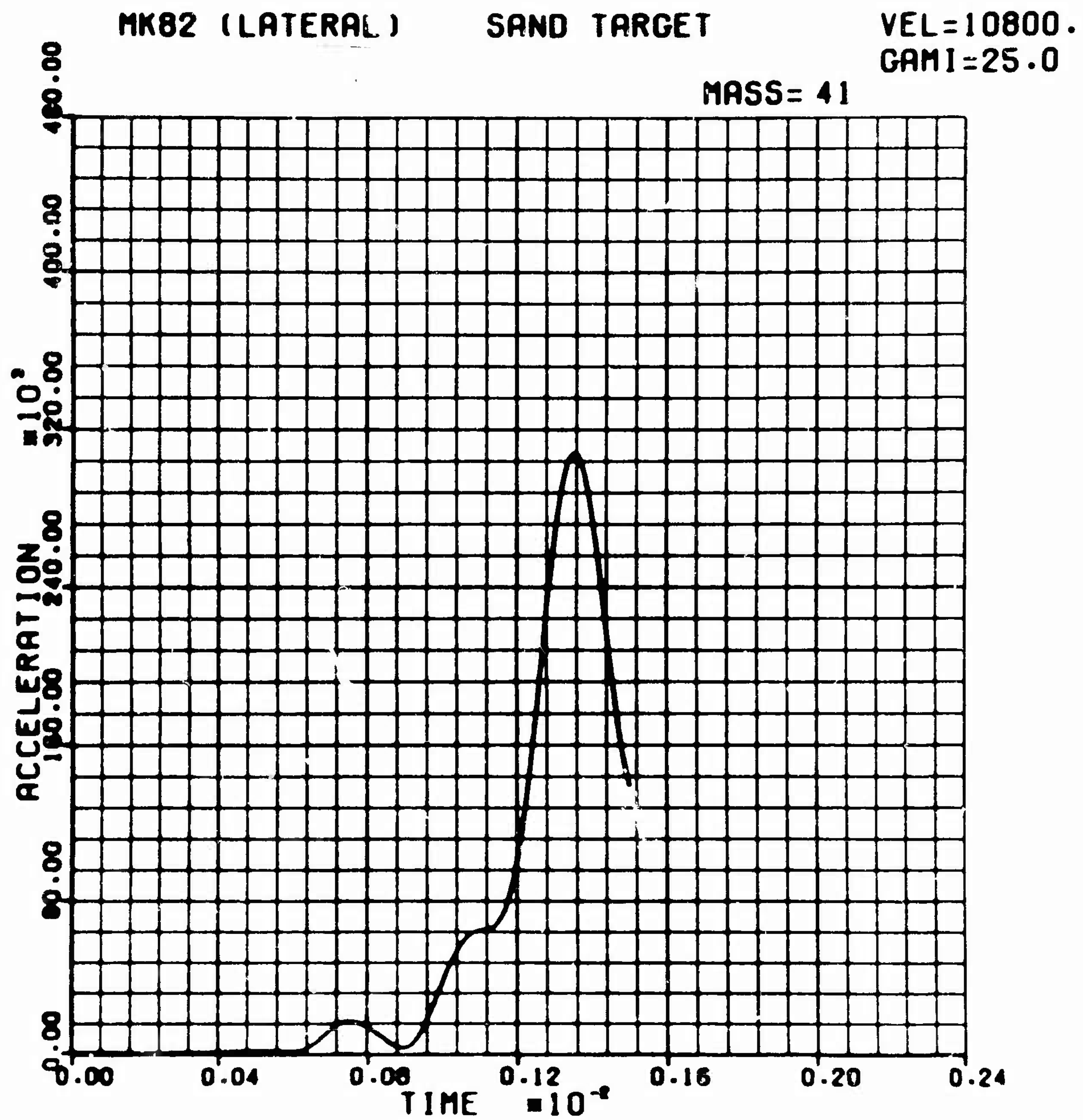

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=55.0
MASS= 43
ACCELERATION *10'
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10

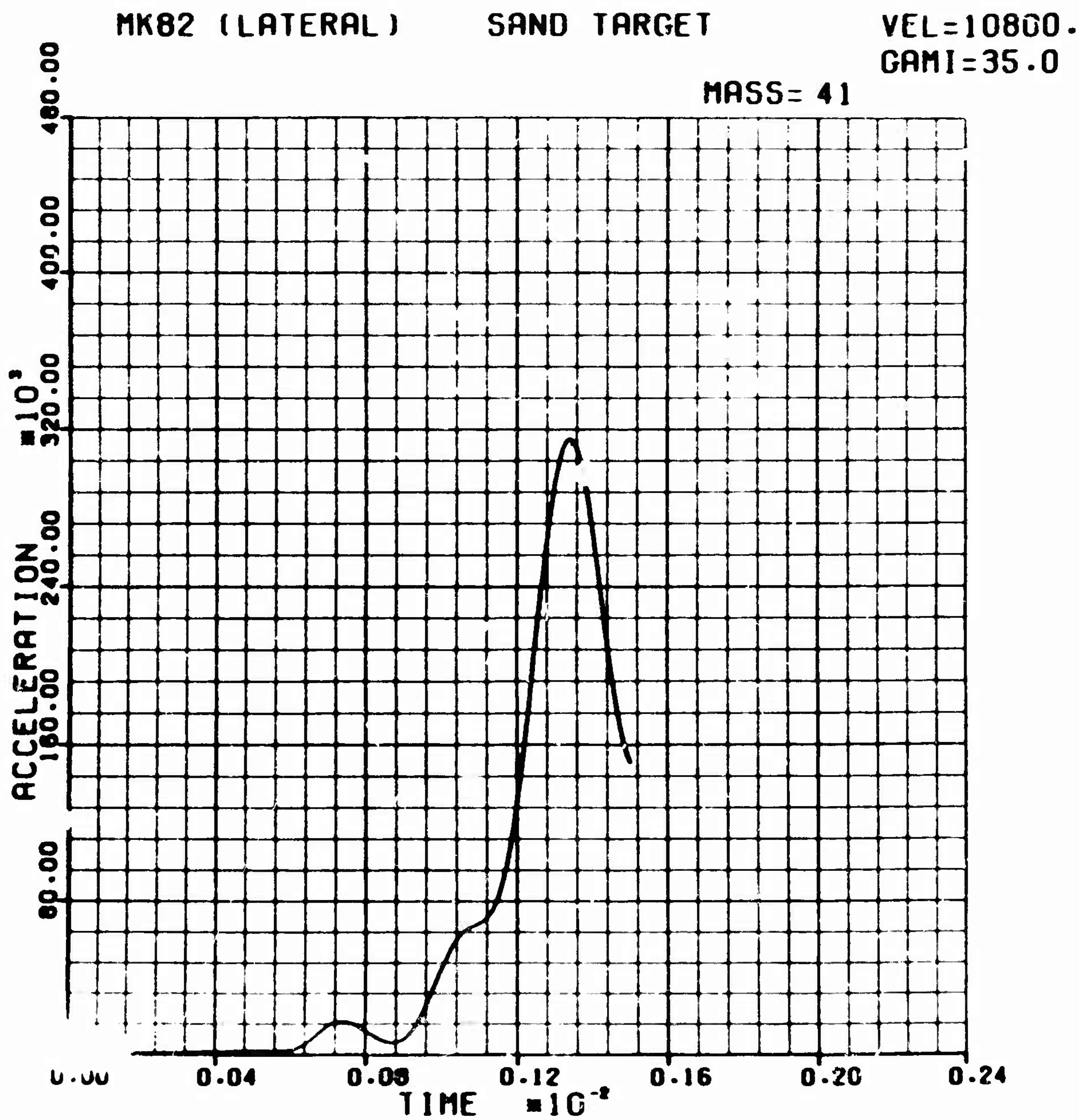

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 43
ACCELERATION $*10^4$
80.00
40.00
-0.00
-40.00
-80.00
-120.00
-160.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$



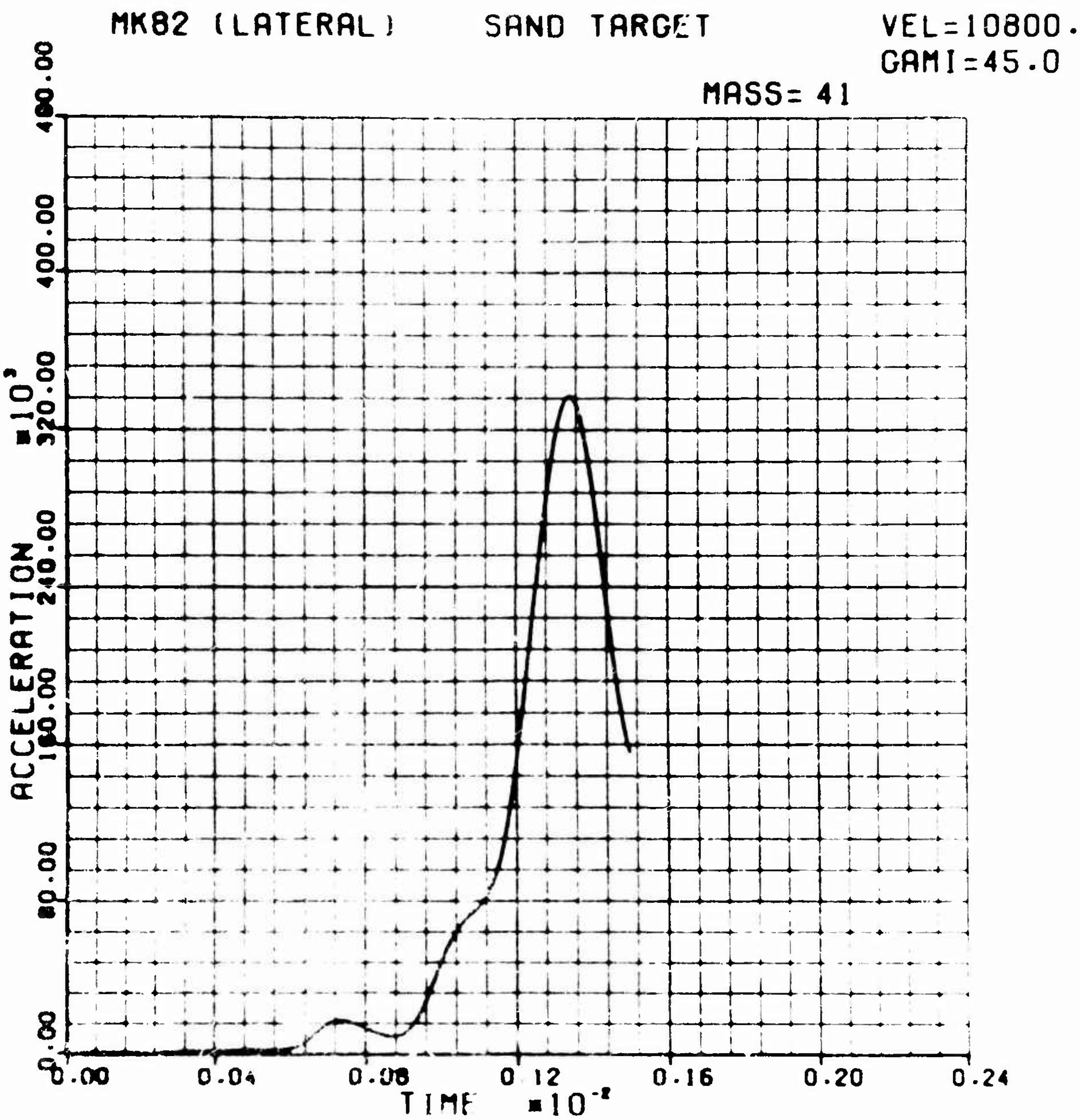
MK82 (LATERAL) SAND TARGET
VEL=10800
GAMI=70.0
MASS= 43
ACCELERATION *10
120.00
80.00
40.00
0.00
-40.00
-80.00
0.00
0.12
0.16
0.20
0.24
TIME


MK82 (LATERAL)
SAND TARGET
VEL=10800.
CAMI=20.0
MASS= 41
ACCELERATION *10^3
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME *10^-2
0.00
0.04
0.08
0.12
0.16
0.20
0.24

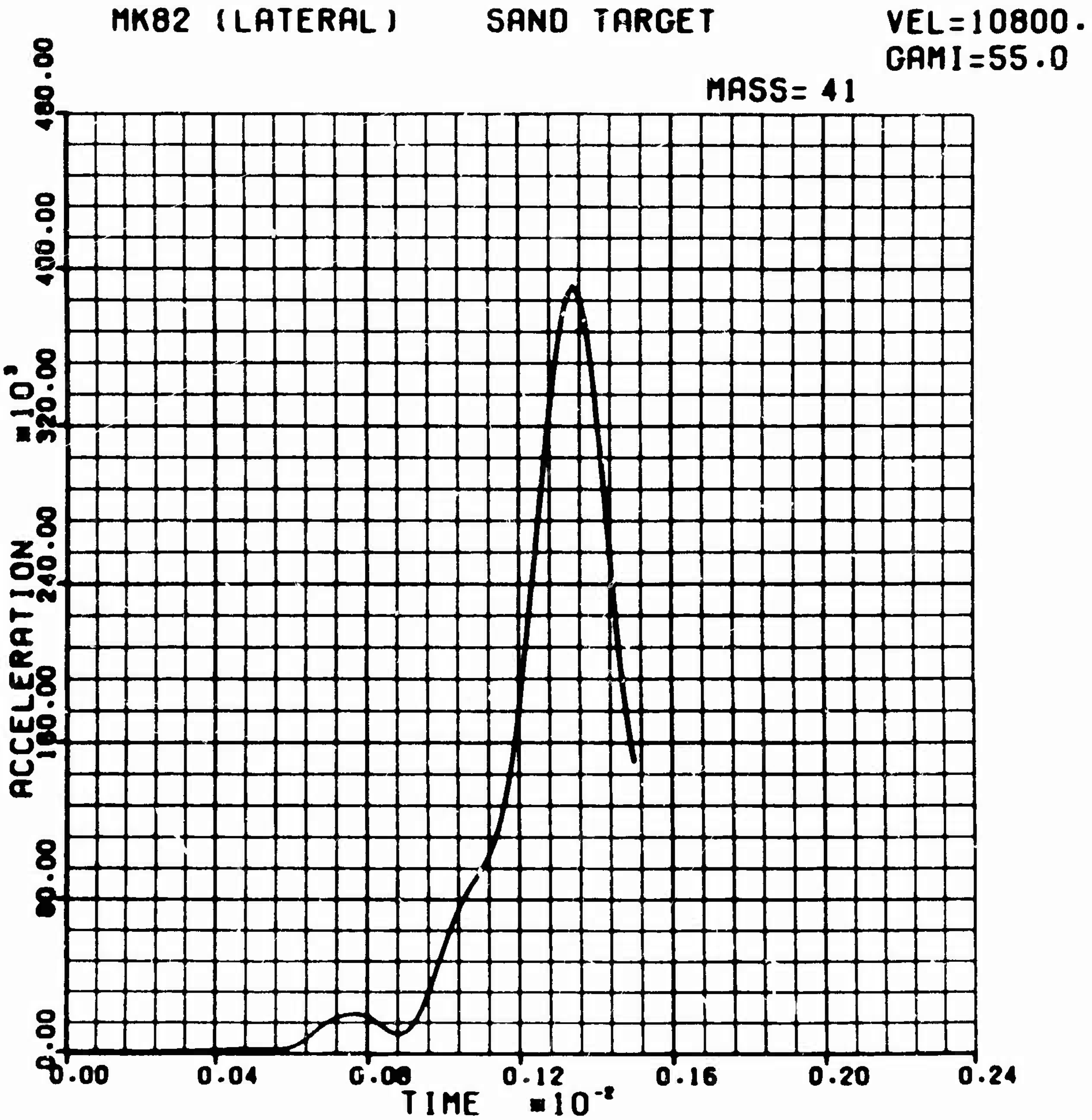

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=25.0
MASS= 41
ACCELERATION *10³
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24
80.00
160.00
240.00
320.00
400.00
480.00



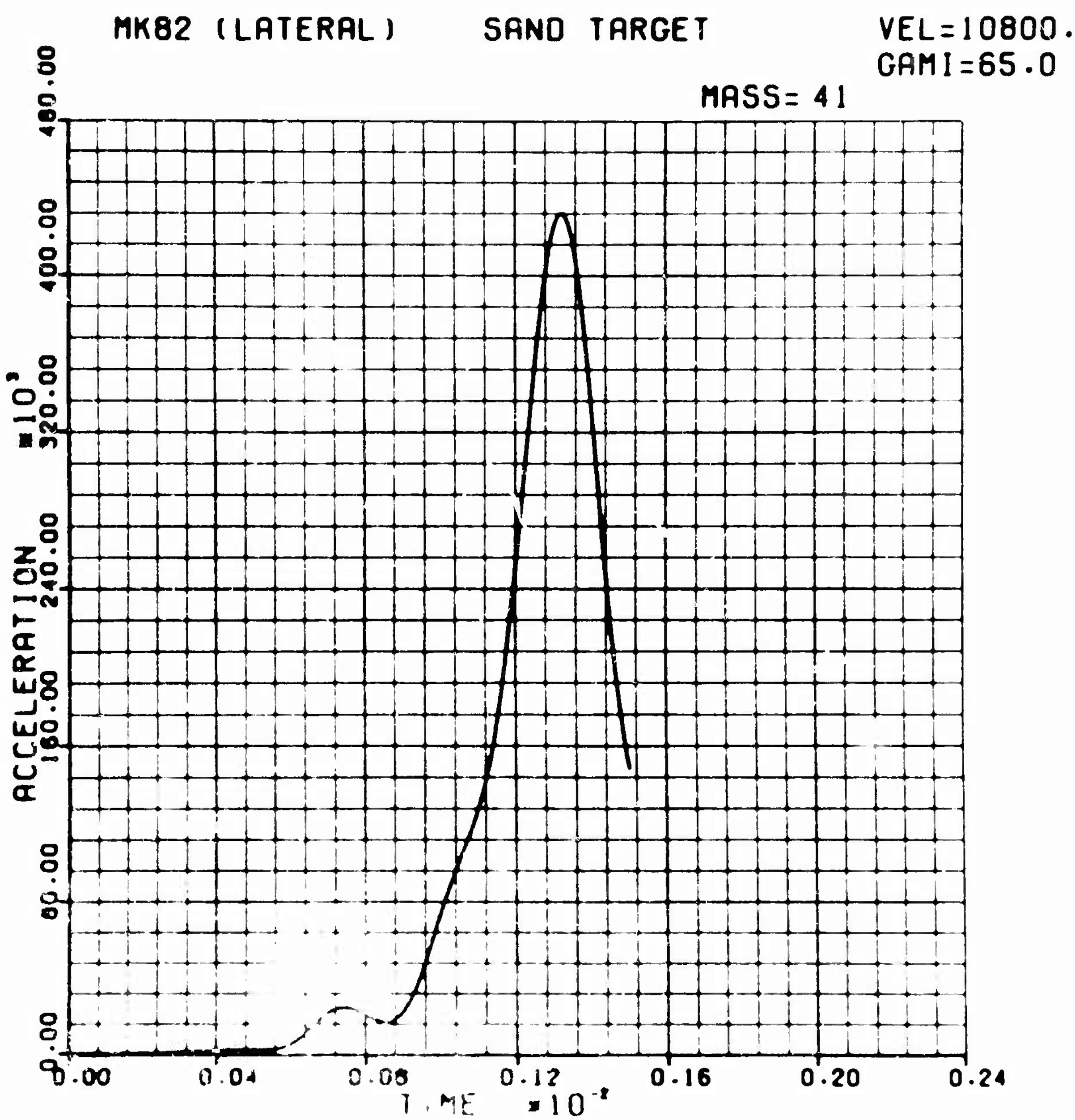
MK82 (LATERAL) SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 41
ACCELERATION *10³
480.00
400.00
320.00
240.00
160.00
80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



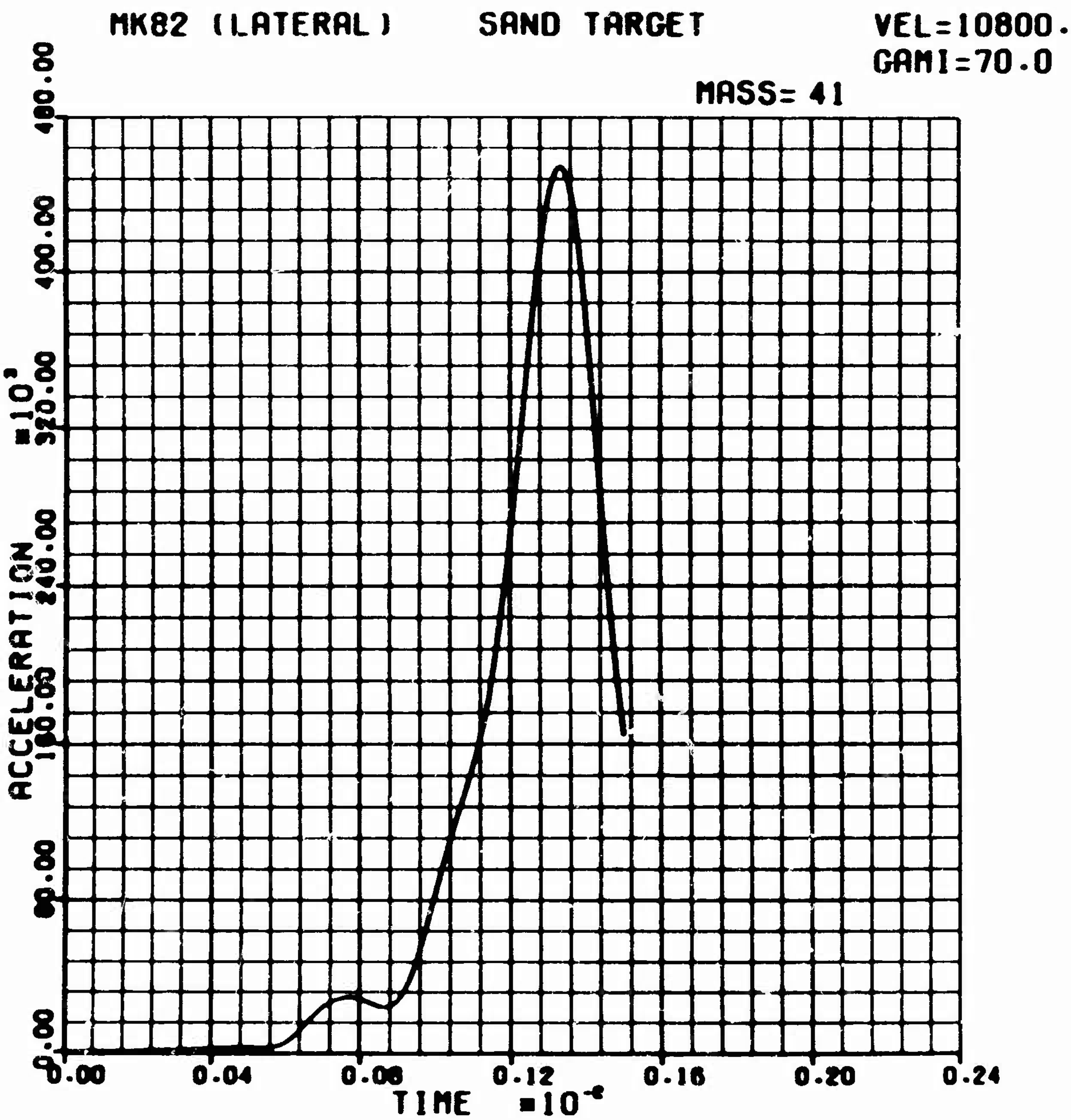
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 41
ACCELERATION ×10³
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME ×10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24



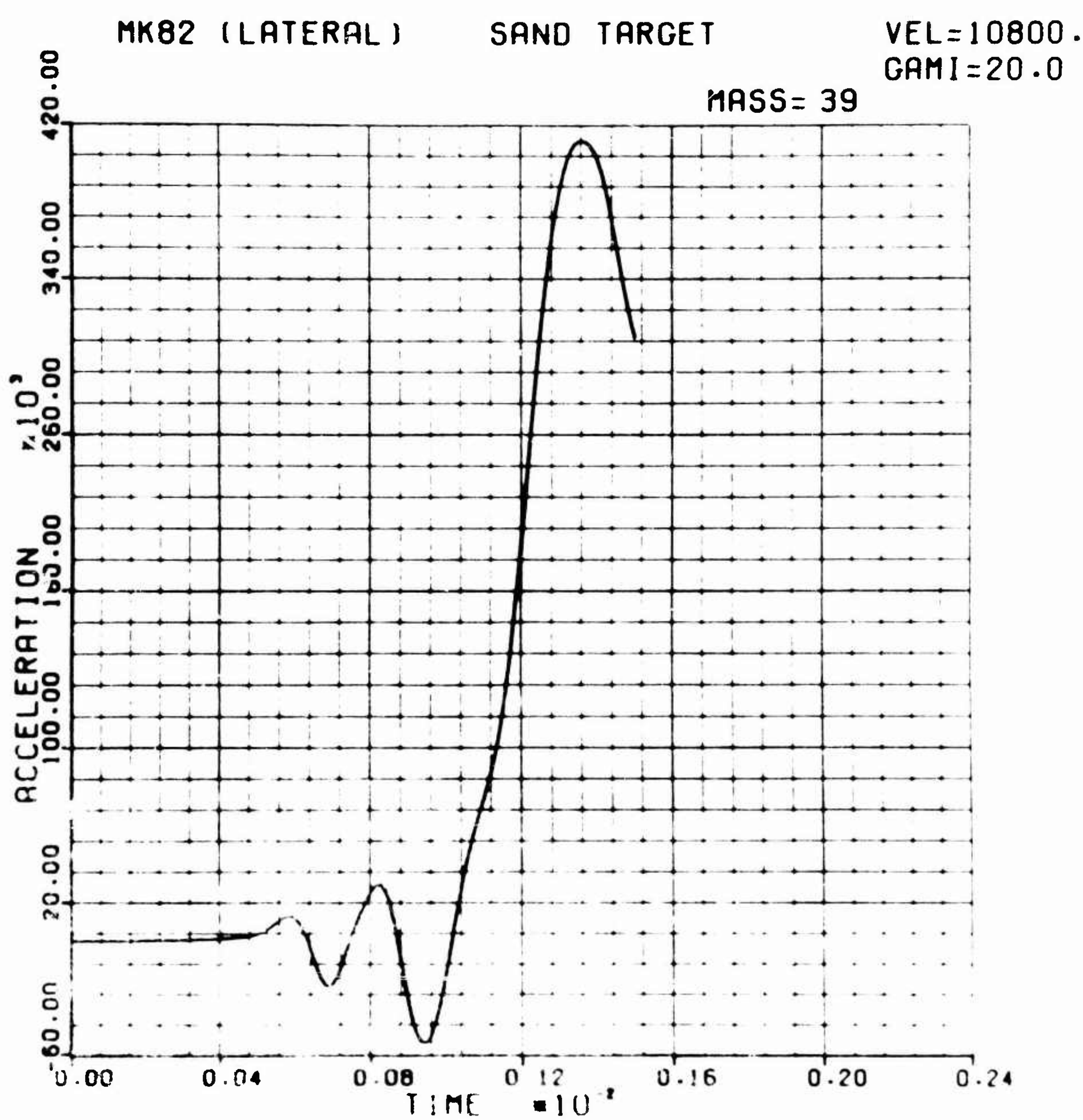
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=55.0
MASS= 41
ACCELERATION *10³
0.00
80.00
160.00
240.00
320.00
400.00
480.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



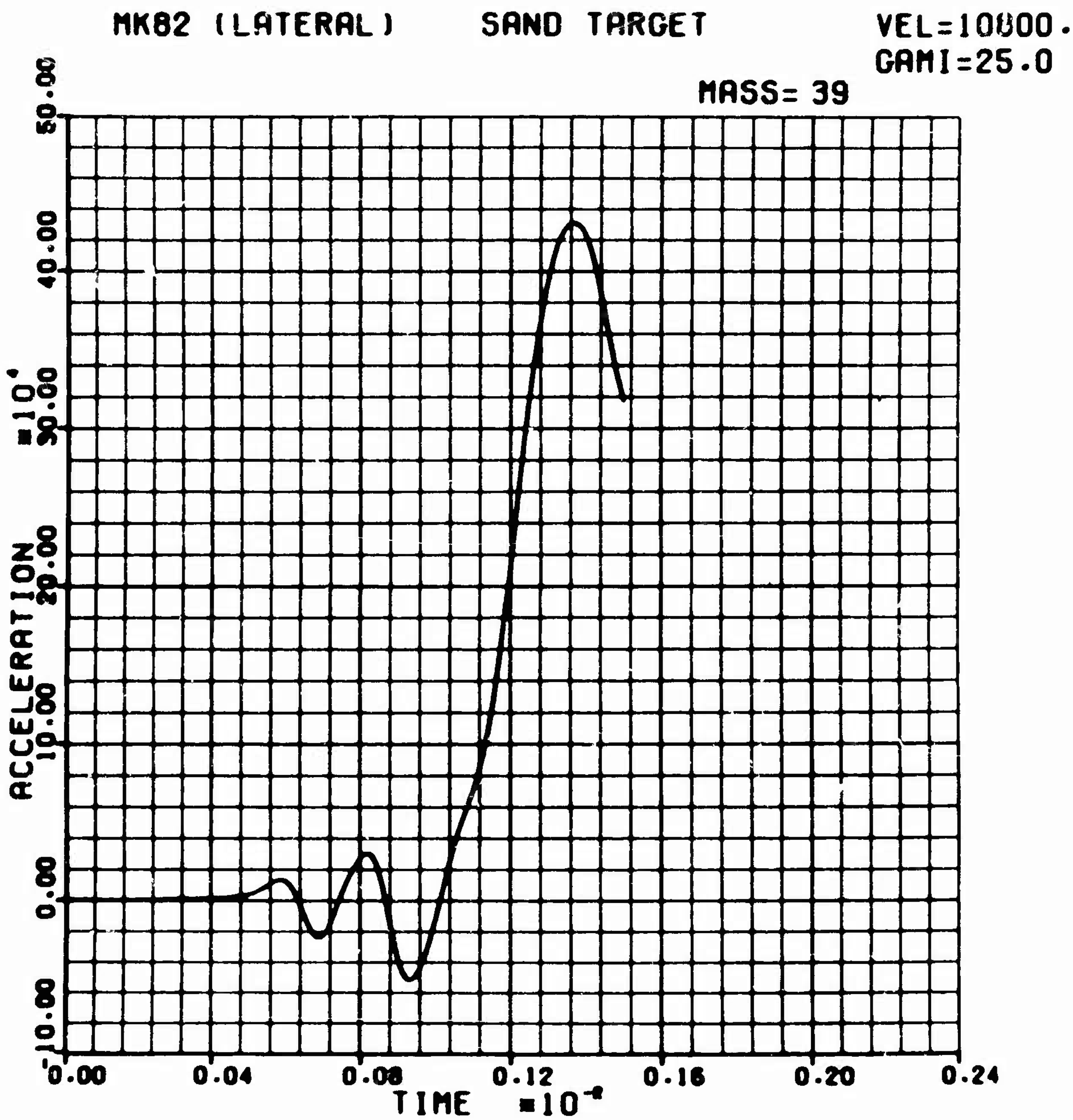
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 41
ACCELERATION *10³
0.00
80.00
160.00
240.00
320.00
400.00
480.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

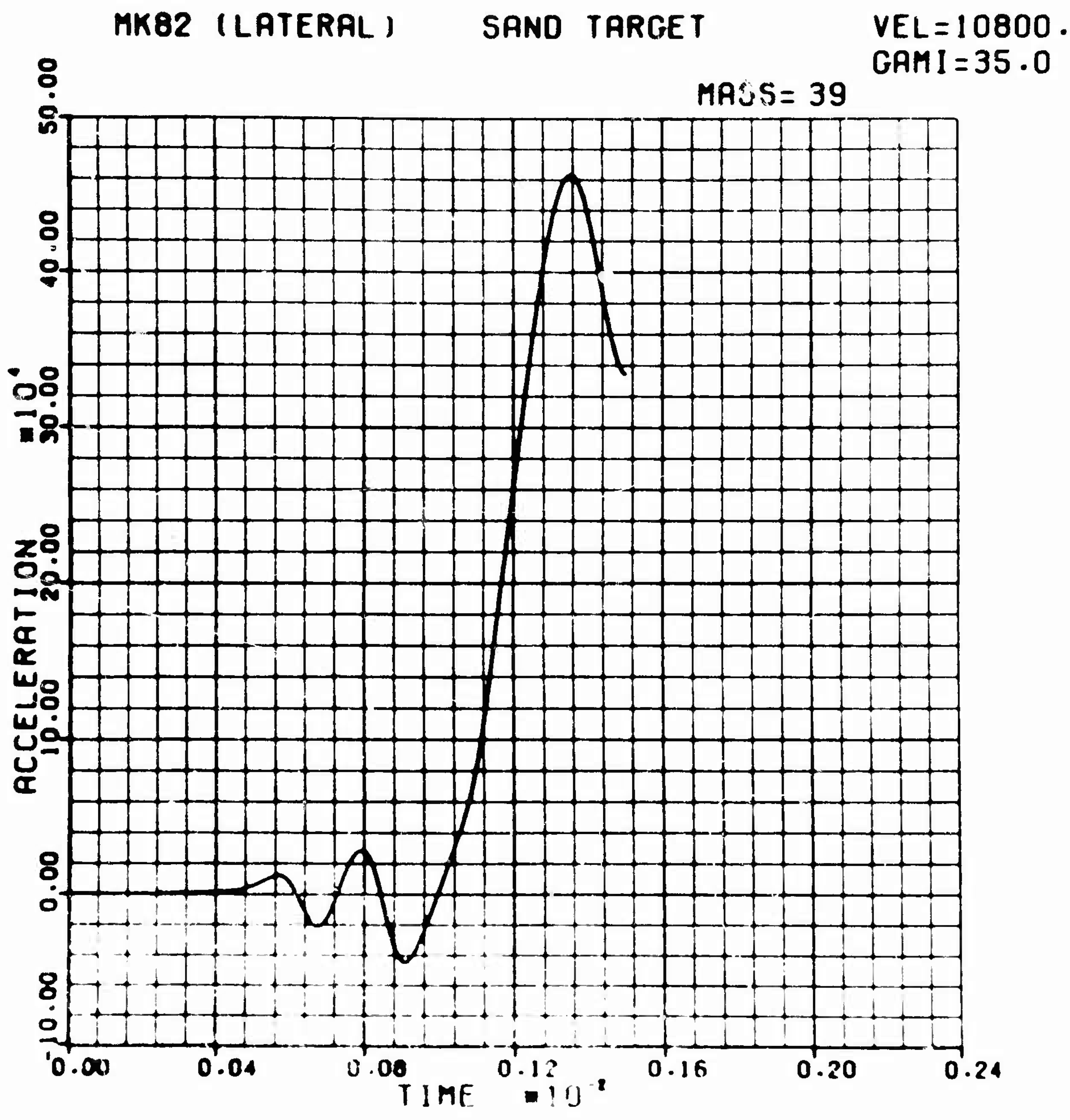


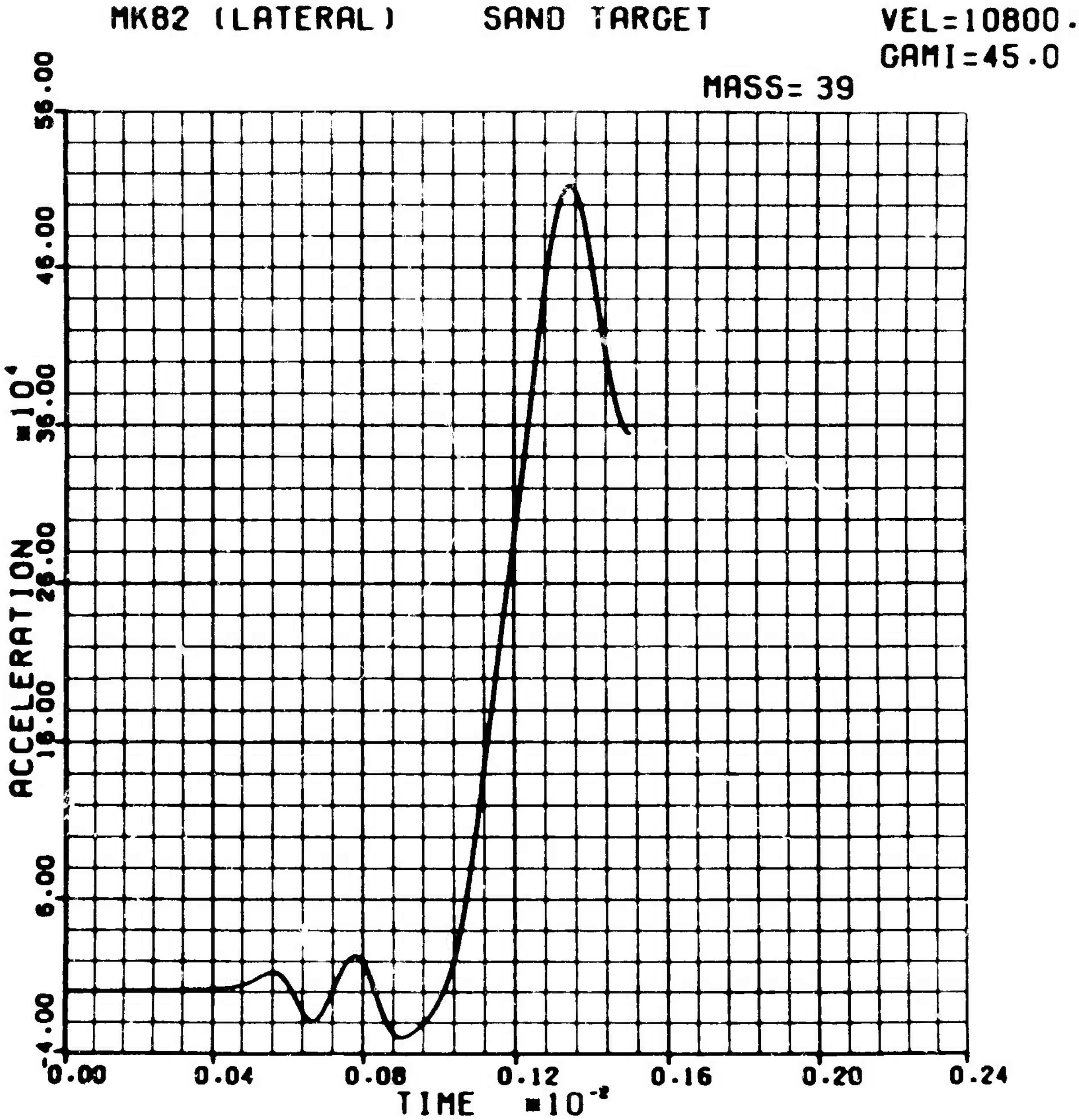
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=70.0
MASS= 41
ACCELERATION *10³
0.00
80.00
160.00
240.00
320.00
400.00
480.00
TIME *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
0.24

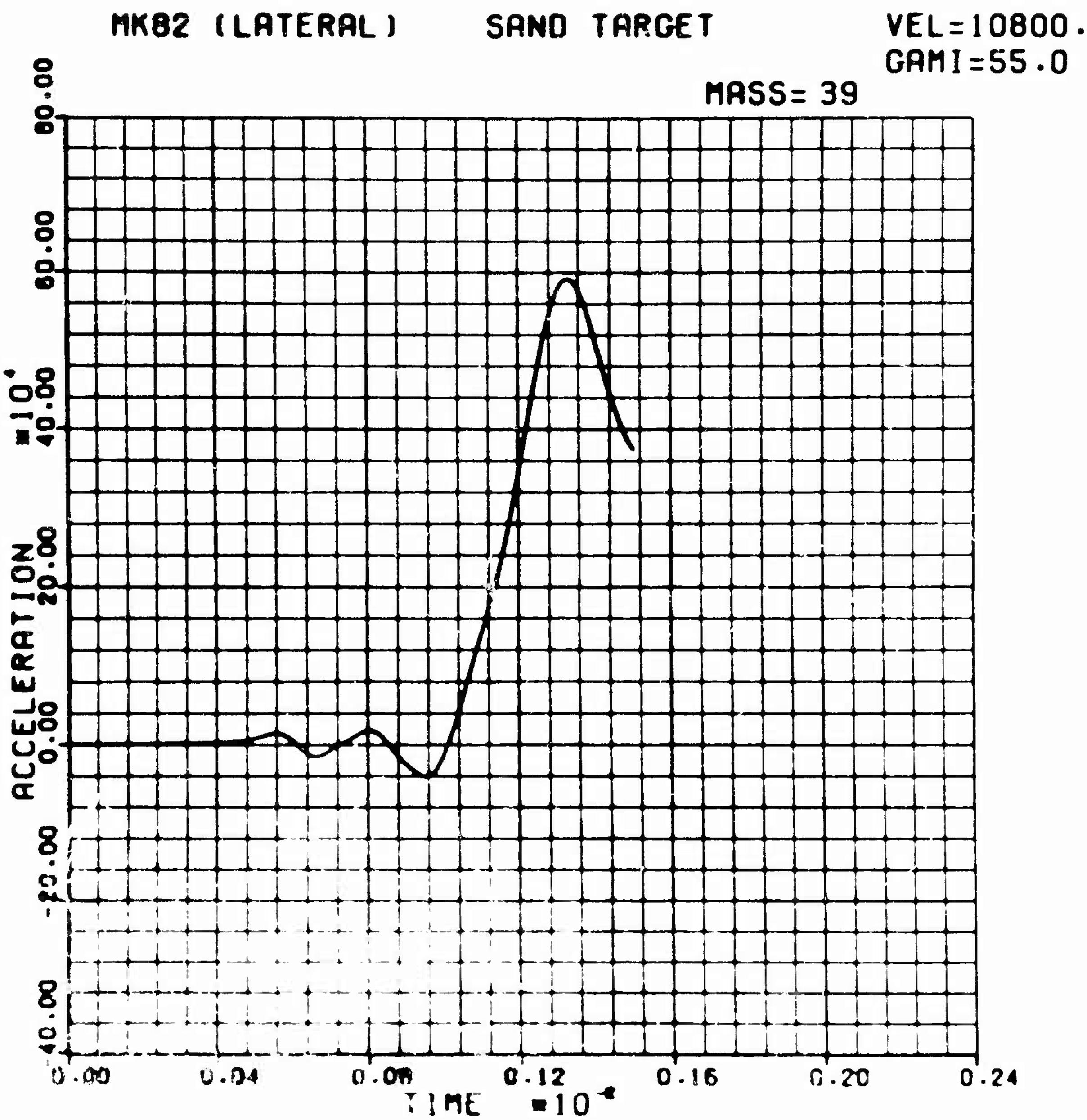


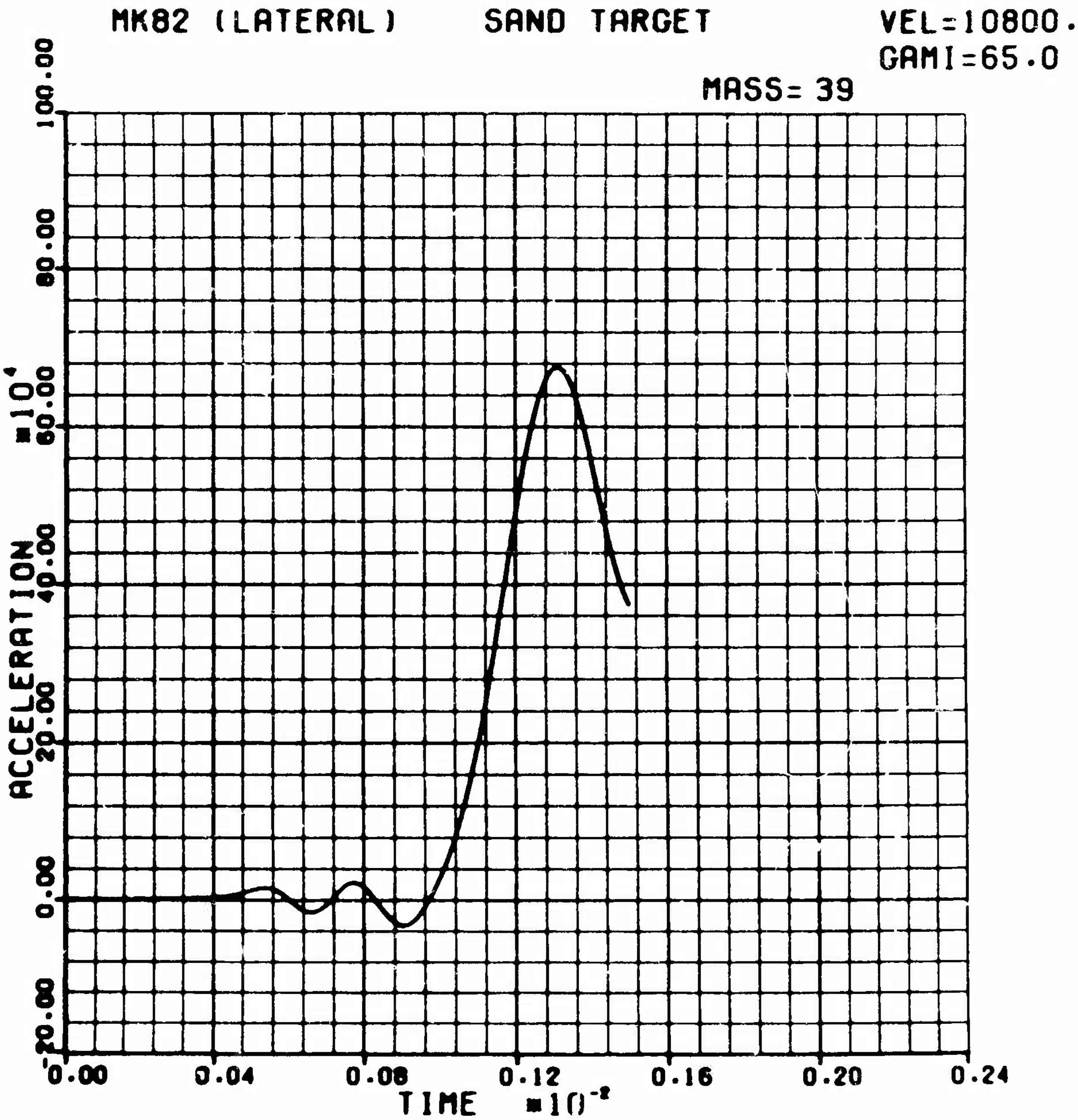
MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=20.0
MASS= 39
ACCELERATION
x10³
420.00
340.00
260.00
180.00
100.00
20.00
-60.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻¹

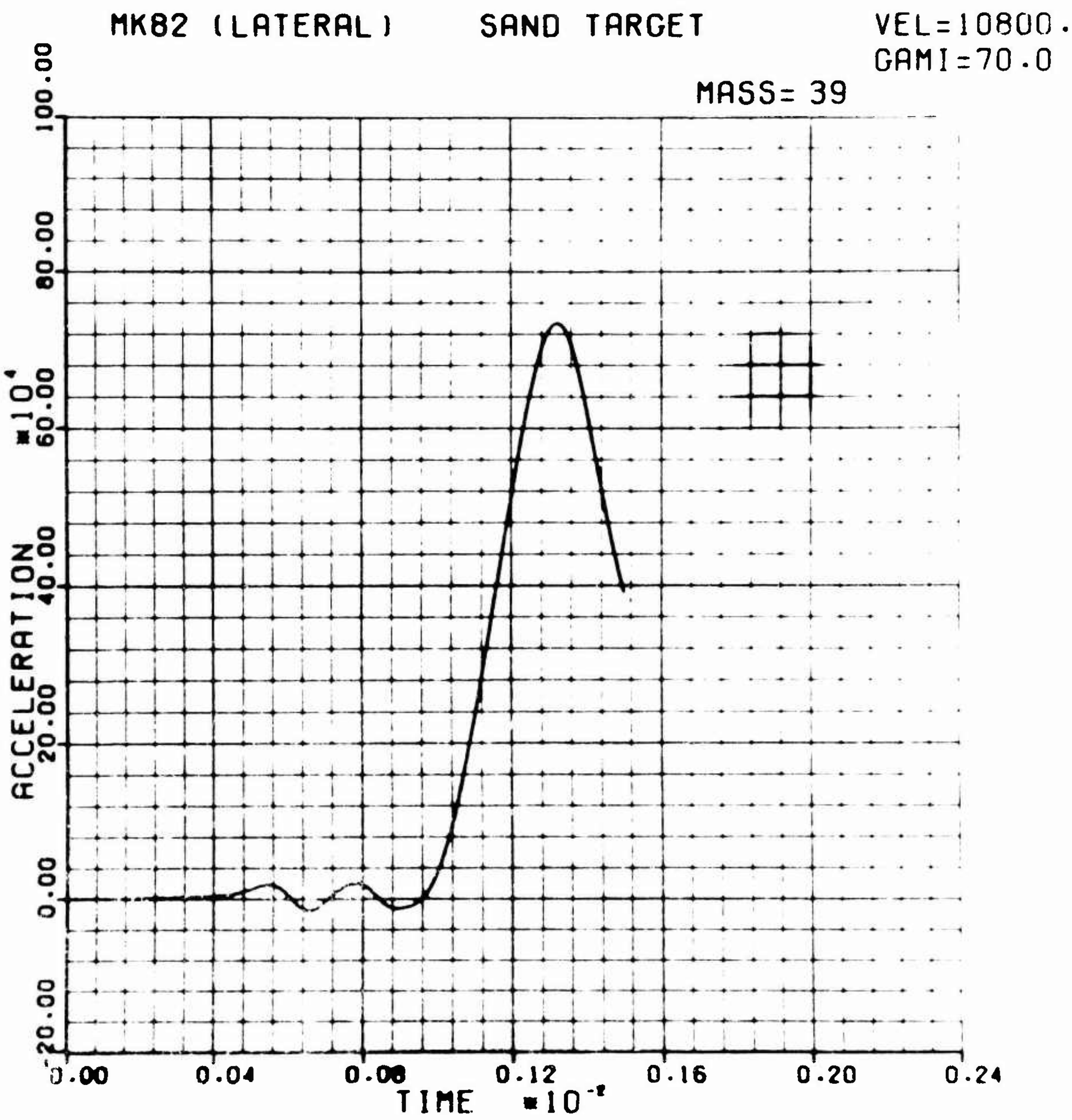

MK82 (LATERAL)
SAND TARGET
VEL=10000.
GAMI=25.0
MASS= 39
ACCELERATION ×10⁴
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

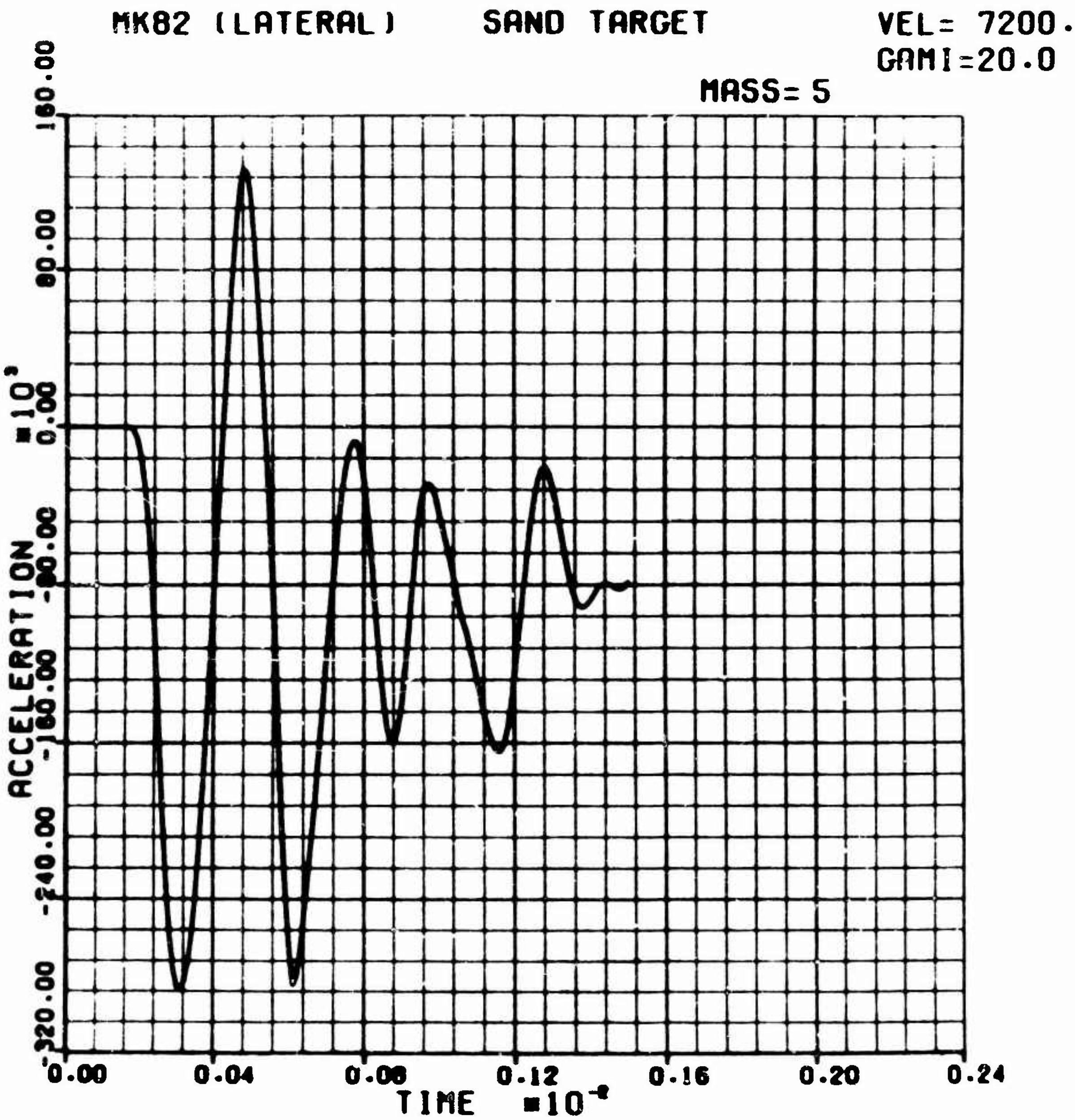

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=35.0
MASS= 39
ACCELERATION *10⁴
TIME *10⁻¹
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=45.0
MASS= 39
ACCELERATION *10⁴
56.00
46.00
36.00
26.00
16.00
6.00
-4.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

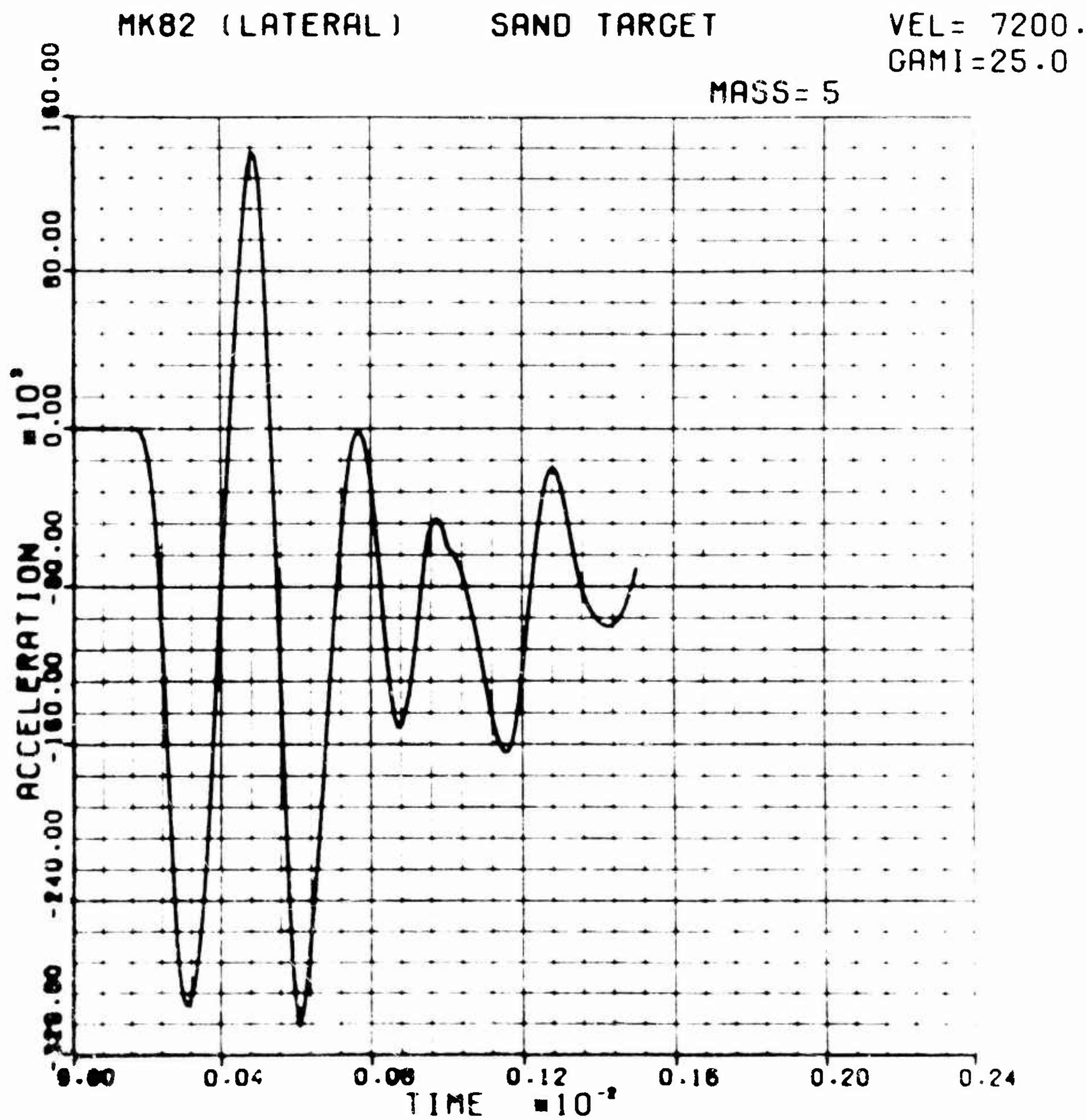

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=55.0
MASS= 39
ACCELERATION *10⁴
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻¹


MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=65.0
MASS= 39
ACCELERATION *10⁴
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

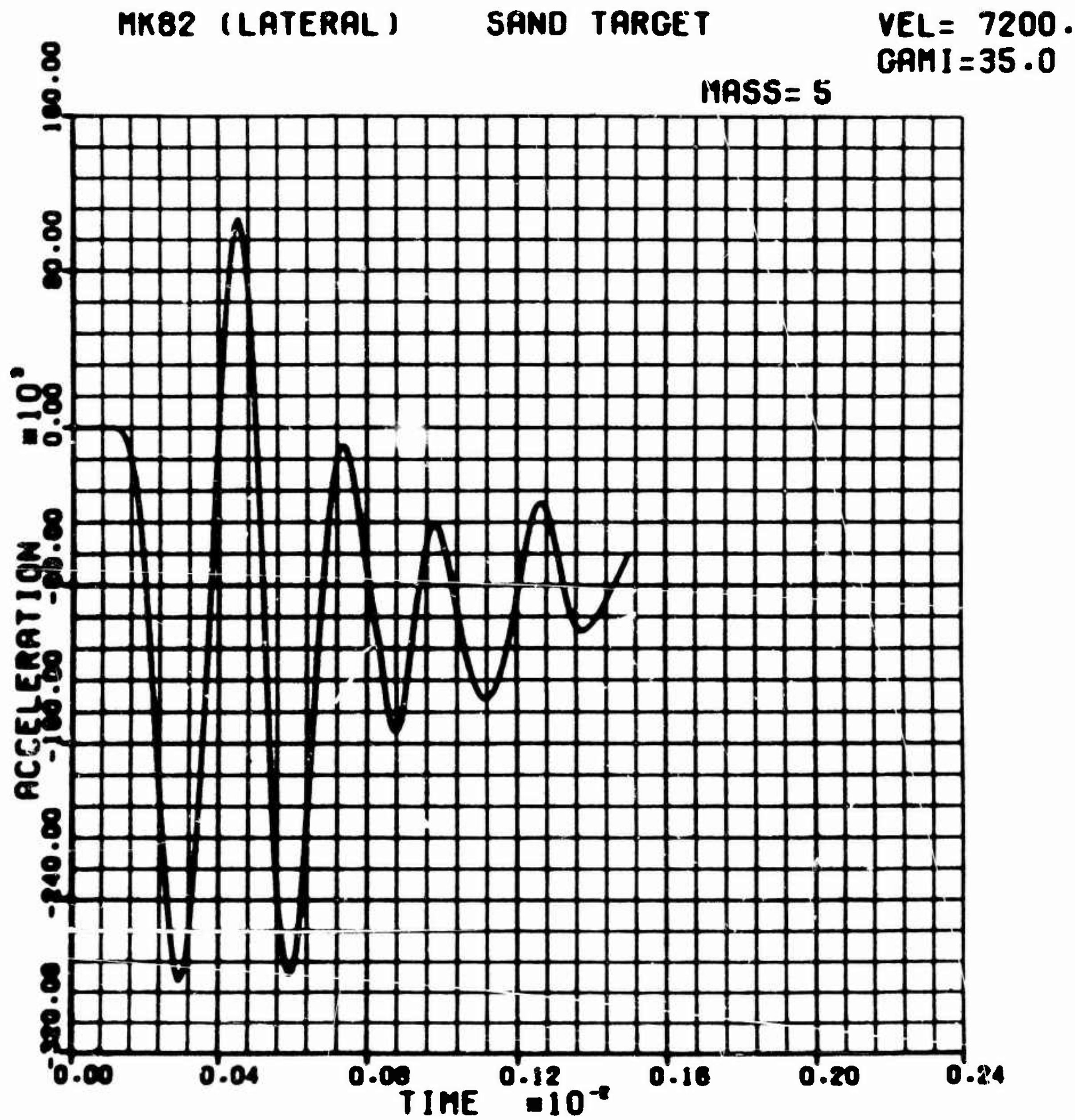

MK82 (LATERAL)
SAND TARGET
VEL=10800.
GAMI=70.0
MASS= 39
ACCELERATION *10^4
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

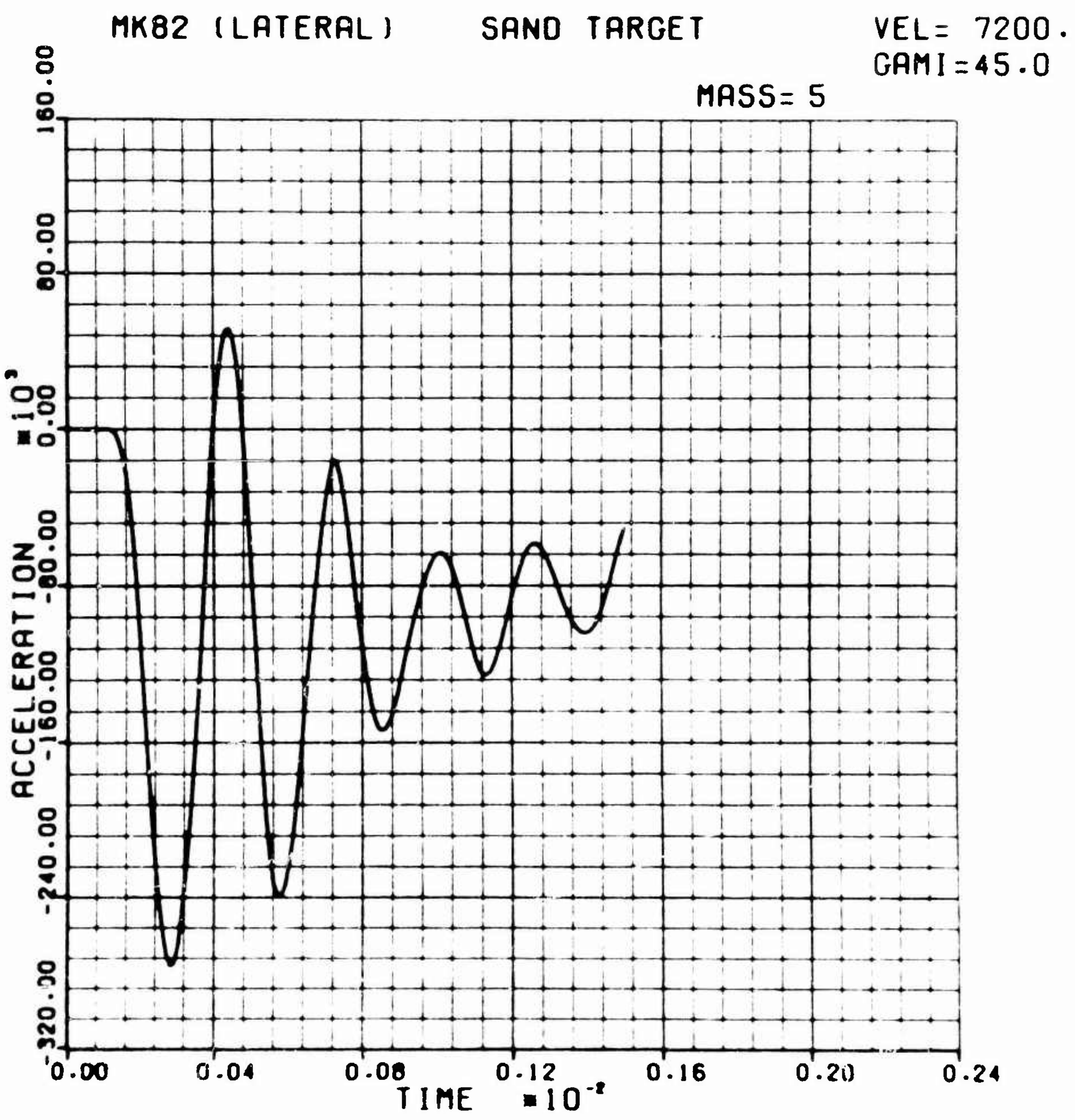


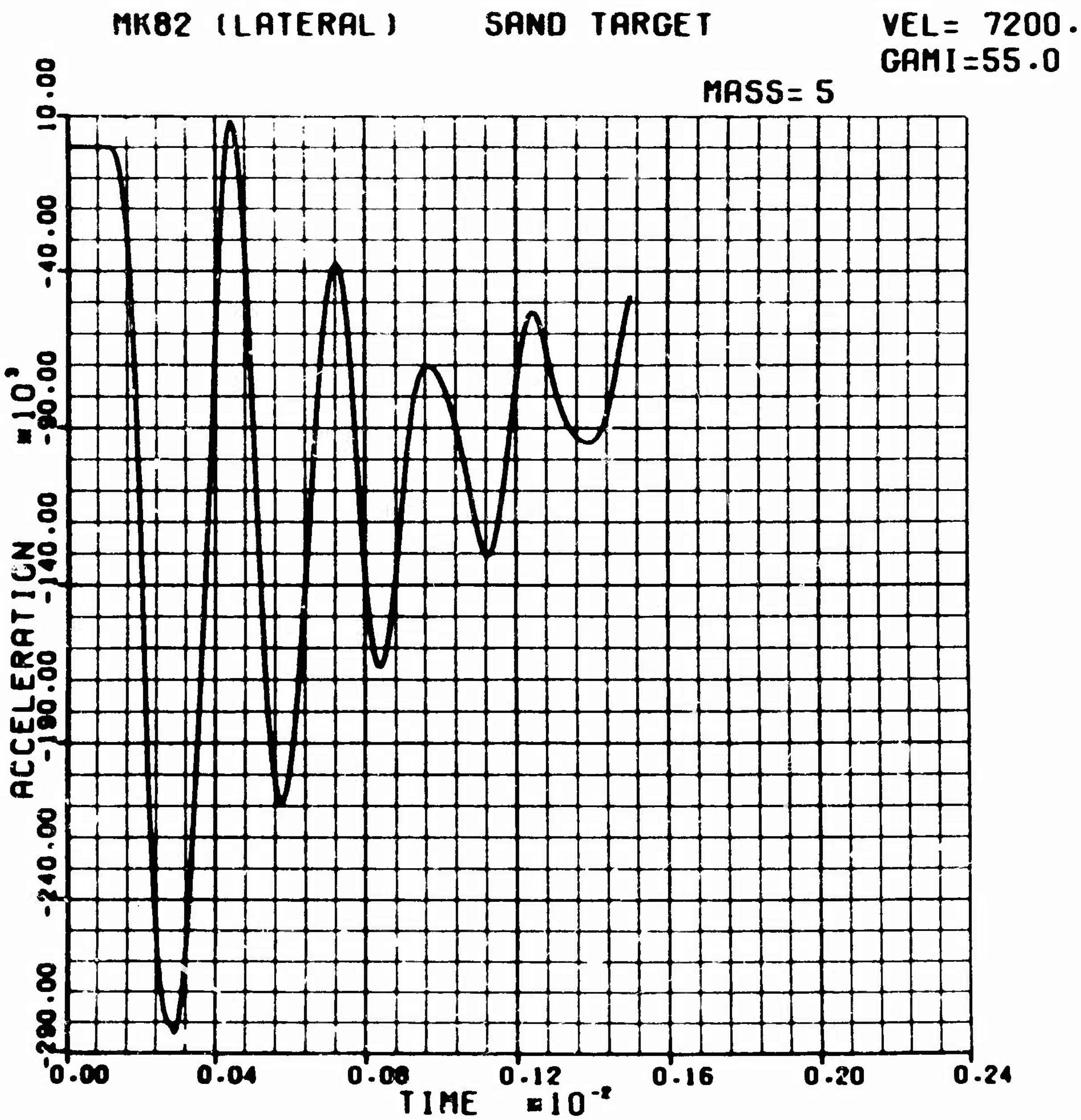
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 5
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
ACCELERATION $*10^3$
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$



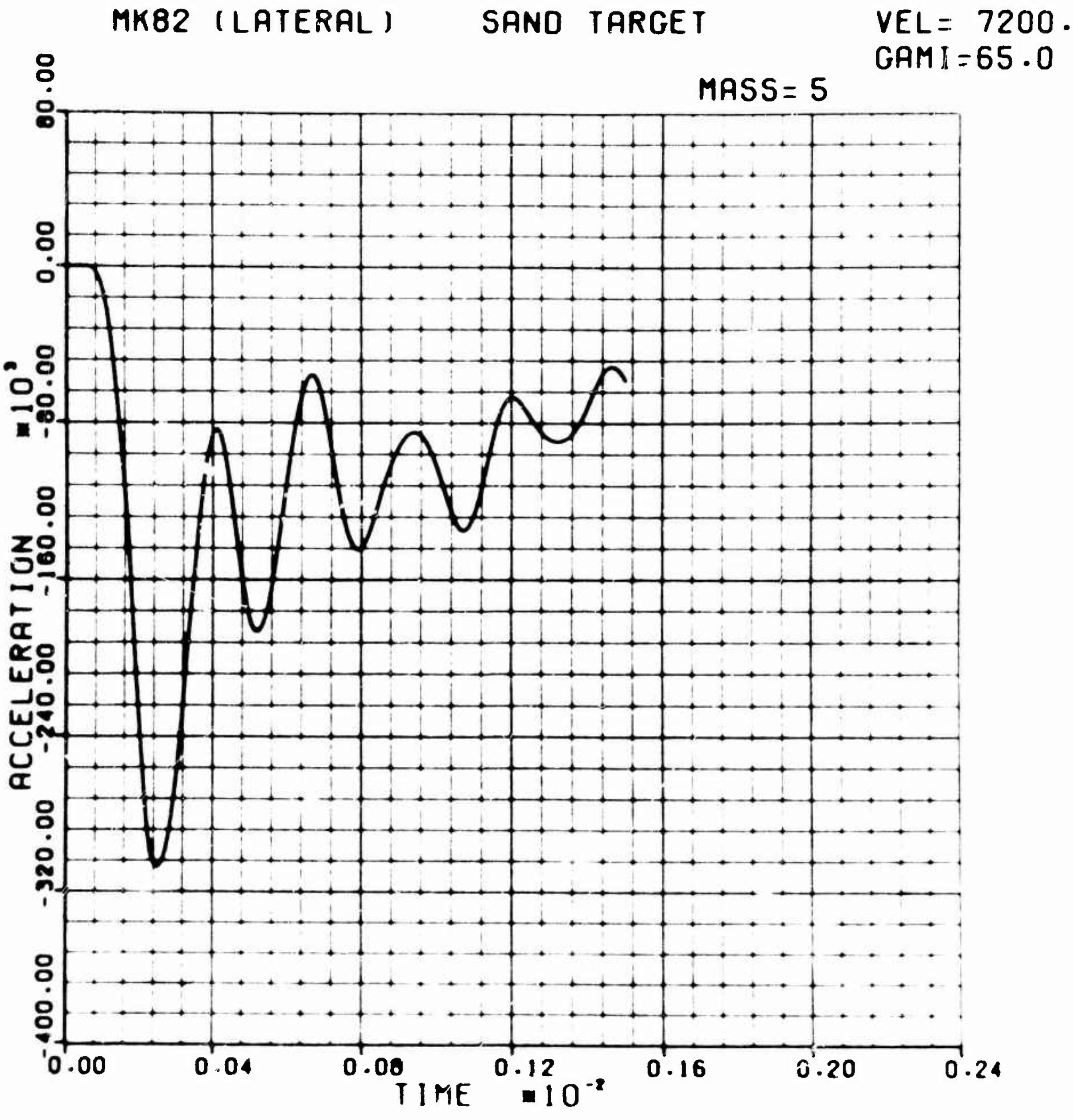
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 5
ACCELERATION *10^3
TIME *10^-2
0.04
0.08
0.12
0.16
0.20
0.24
80.00
0.00
-240.00

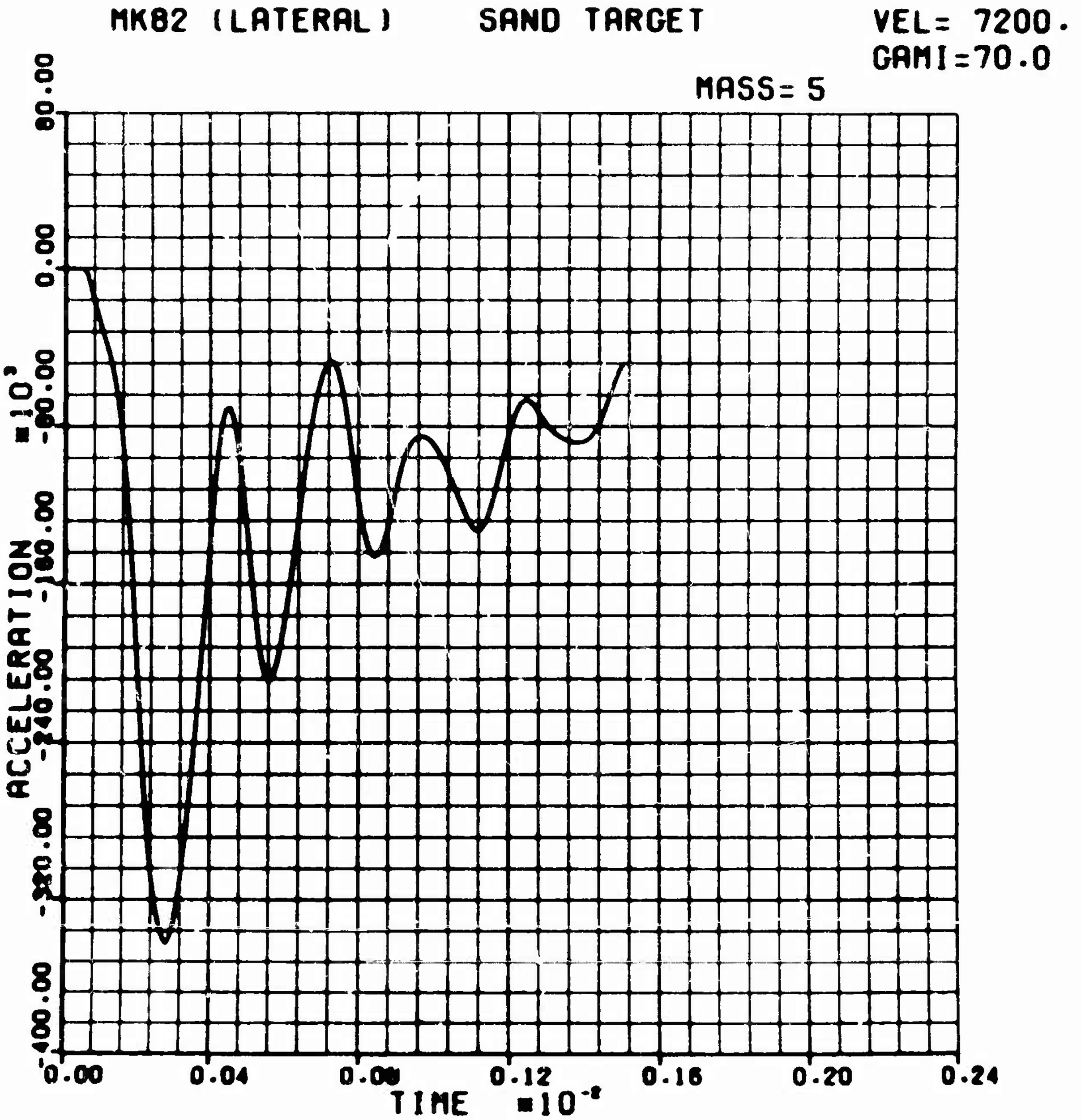

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 5
ACCELERATION *10³
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 5
ACCELERATION *10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

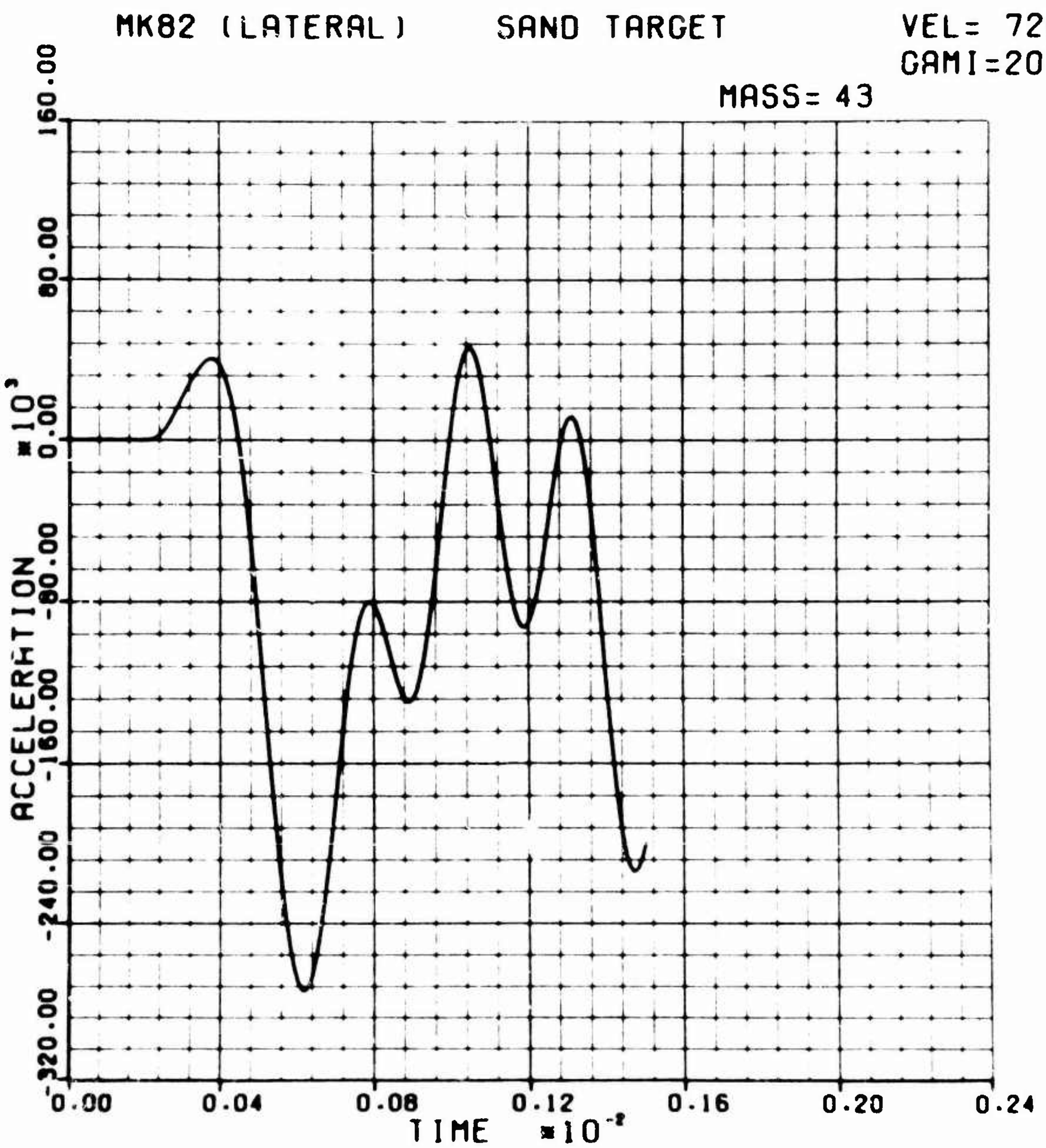


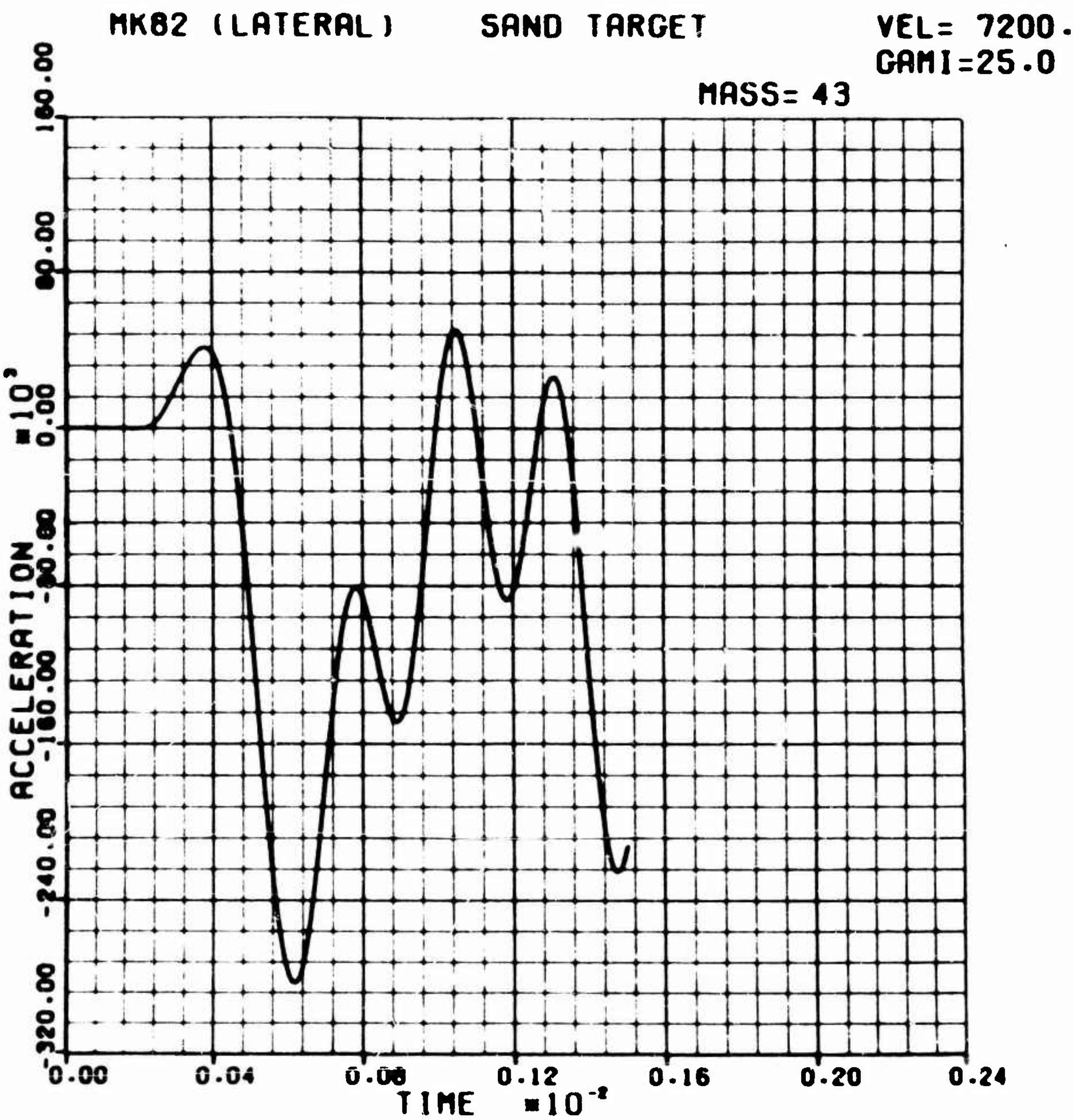
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 5
ACCELERATION ×10³
10.00
-40.00
-90.00
-140.00
-190.00
-240.00
-290.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 5
ACCELERATION $*10^3$
80.00
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
TIME $*10^{-2}$
0.00
0.04
0.08
0.12
0.16
0.20
0.24

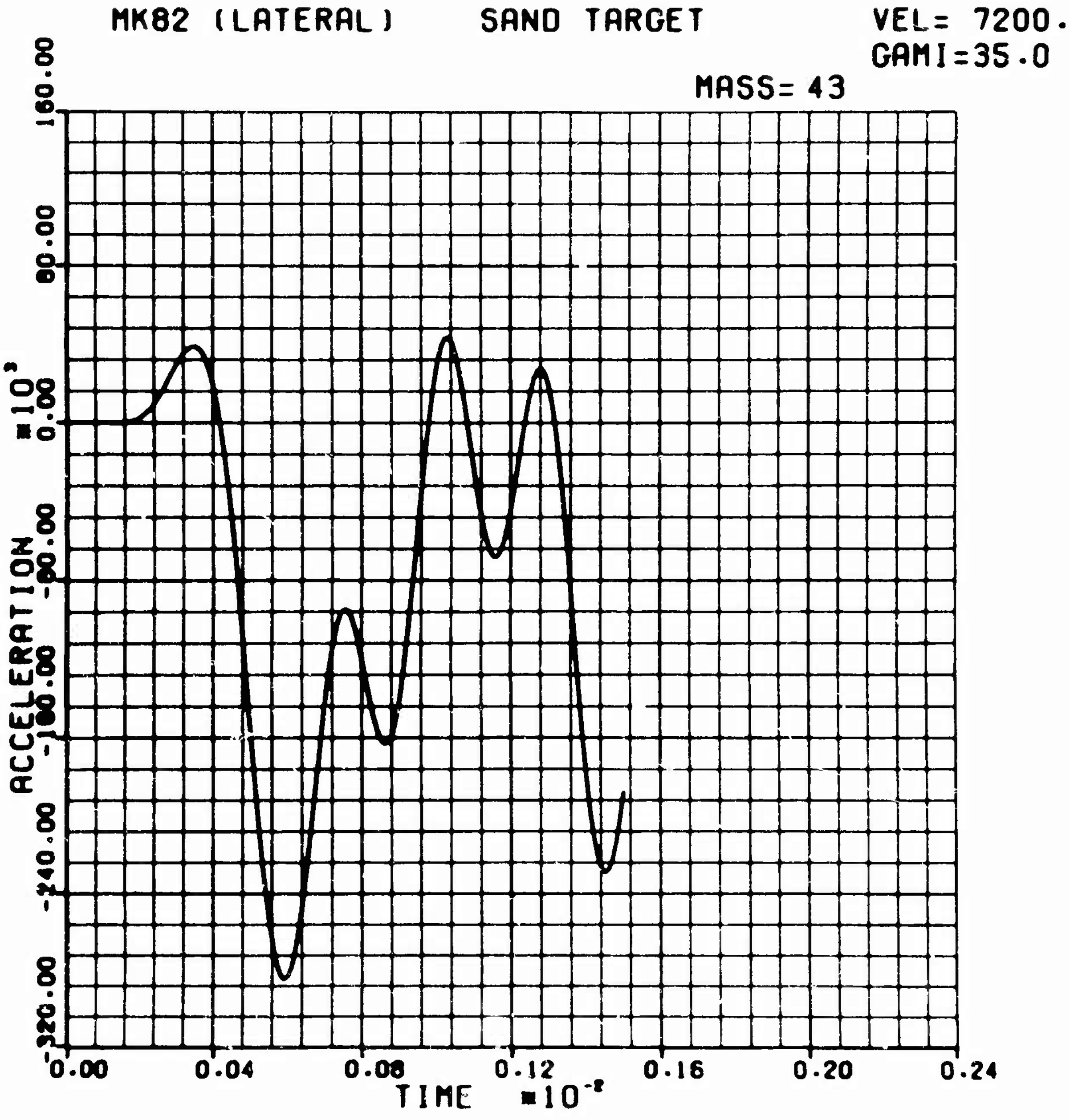


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 5
ACCELERATION *10³
80.00
0.00
-80.00
-160.00
-240.00
-320.00
-400.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

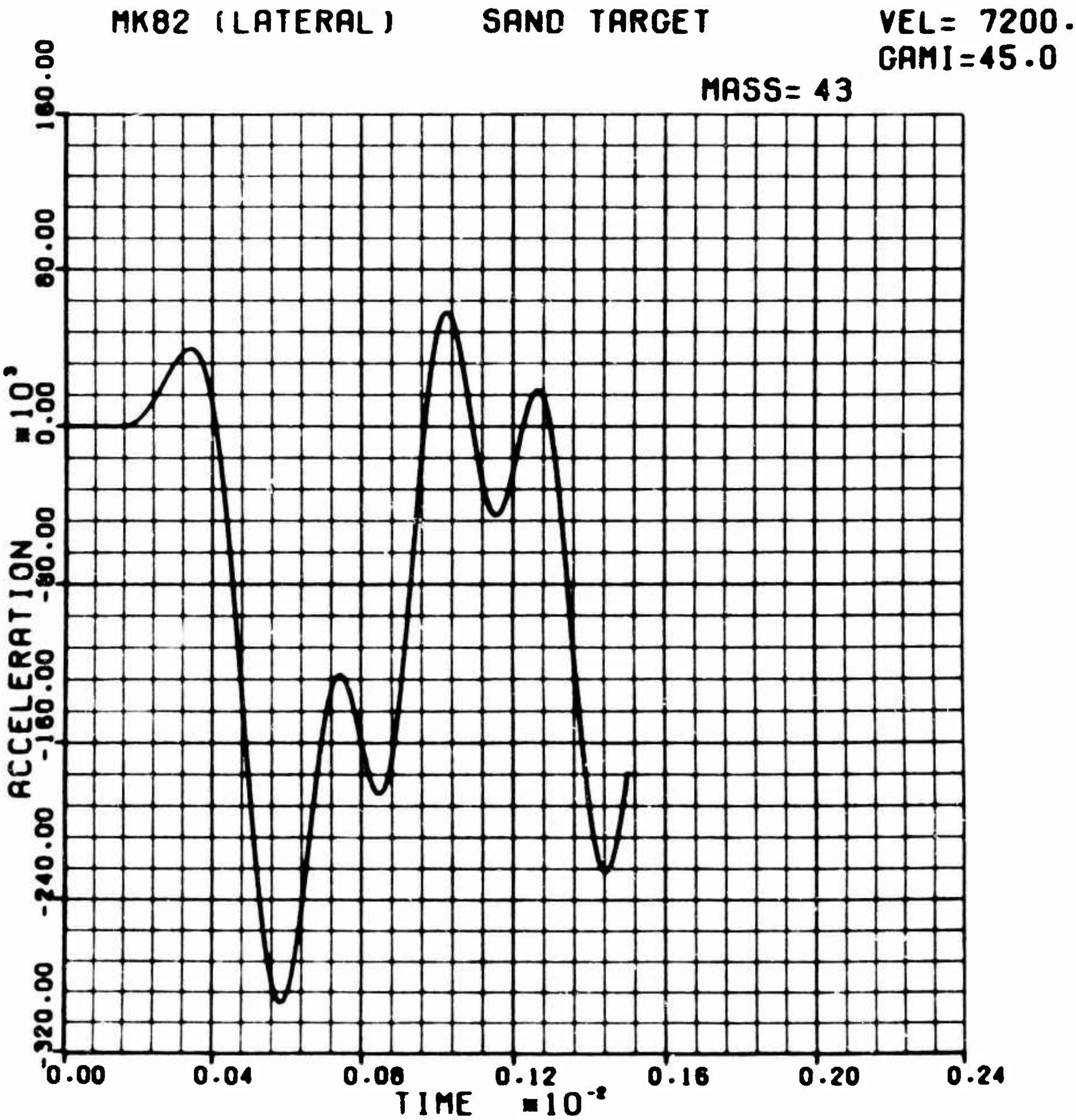

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 43
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
ACCELERATION ×10³
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²



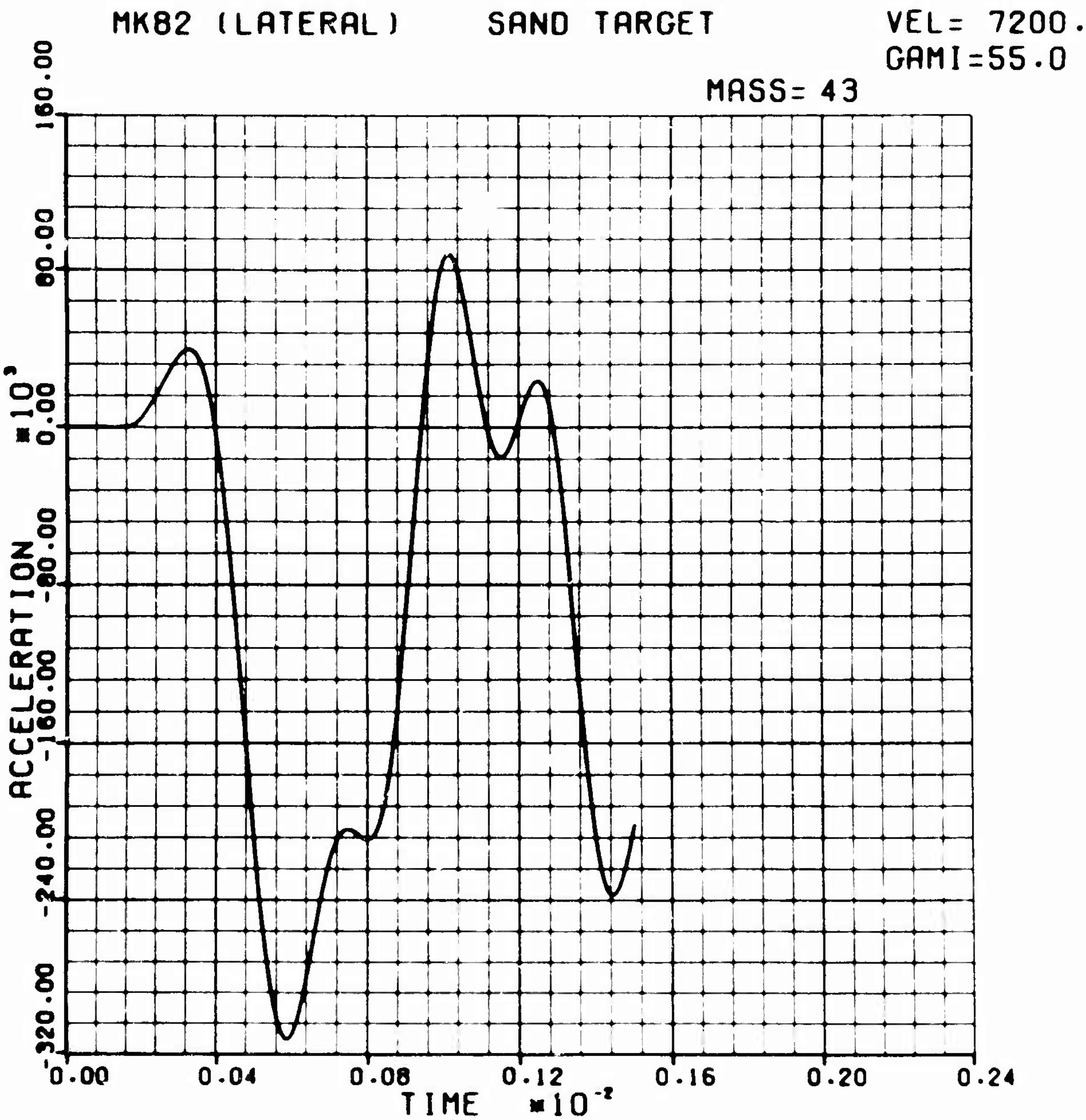
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 43
ACCELERATION *10^3
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2



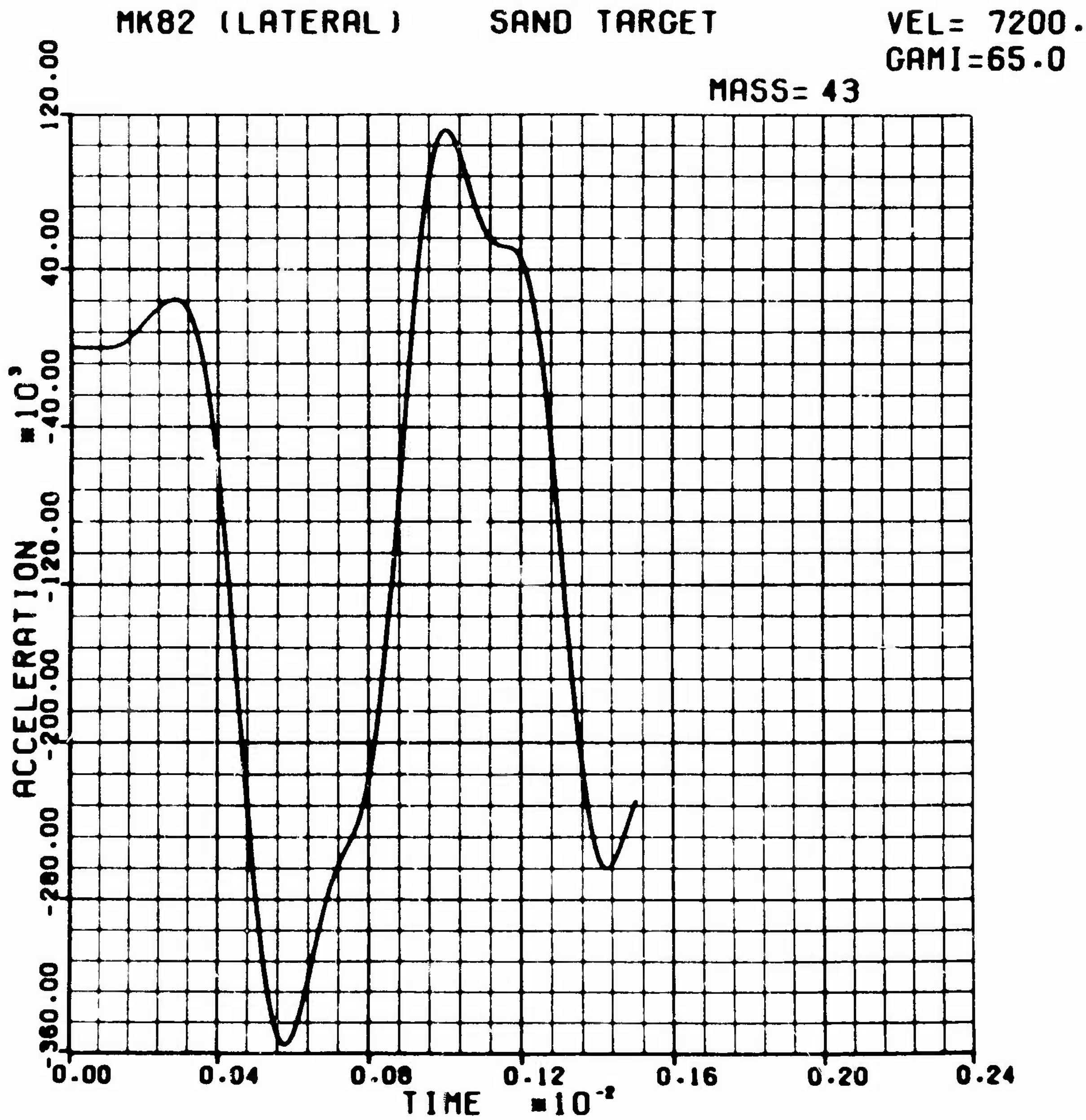
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 43
ACCELERATION ×10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

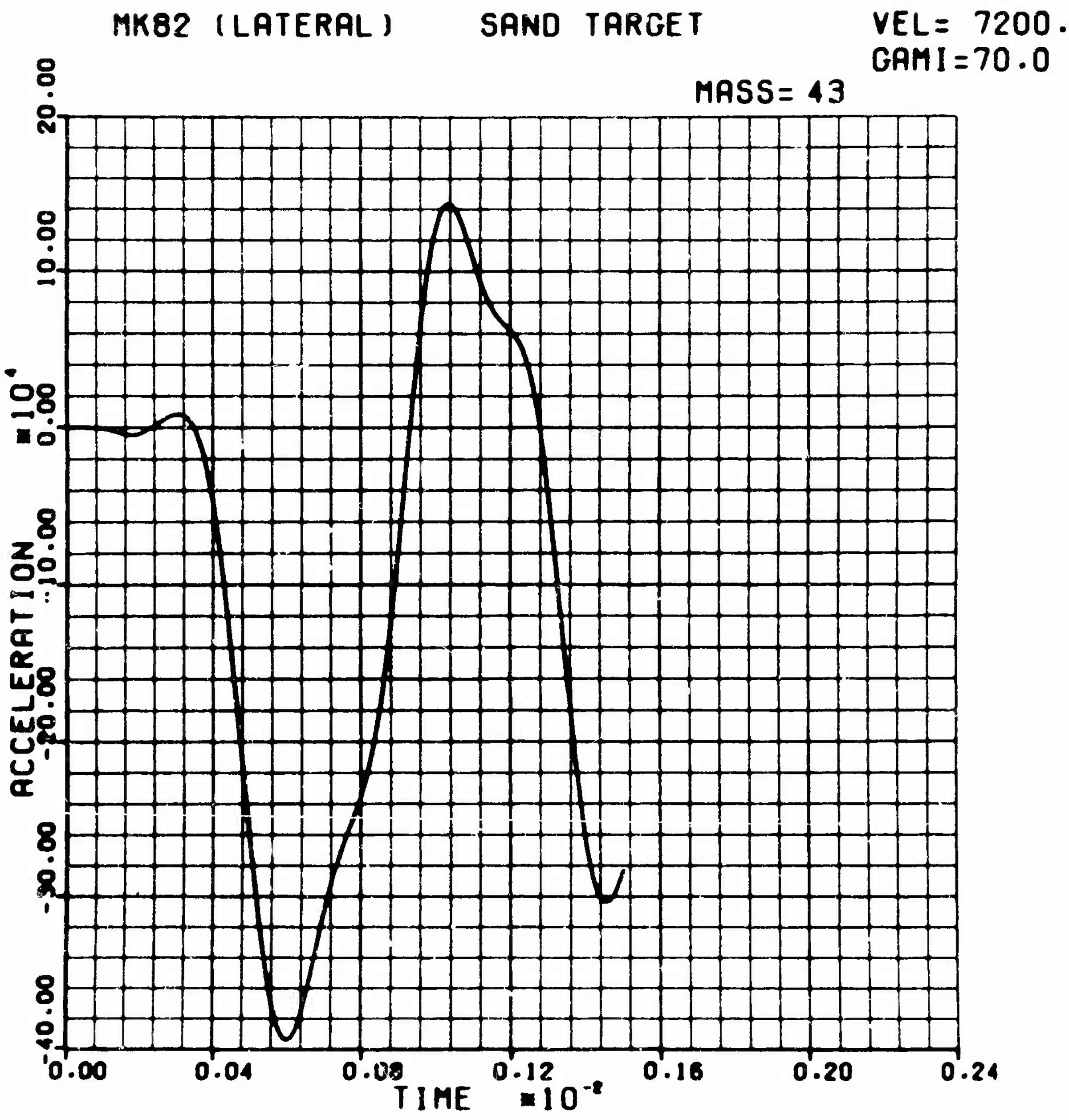


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 43
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
ACCELERATION *10³
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

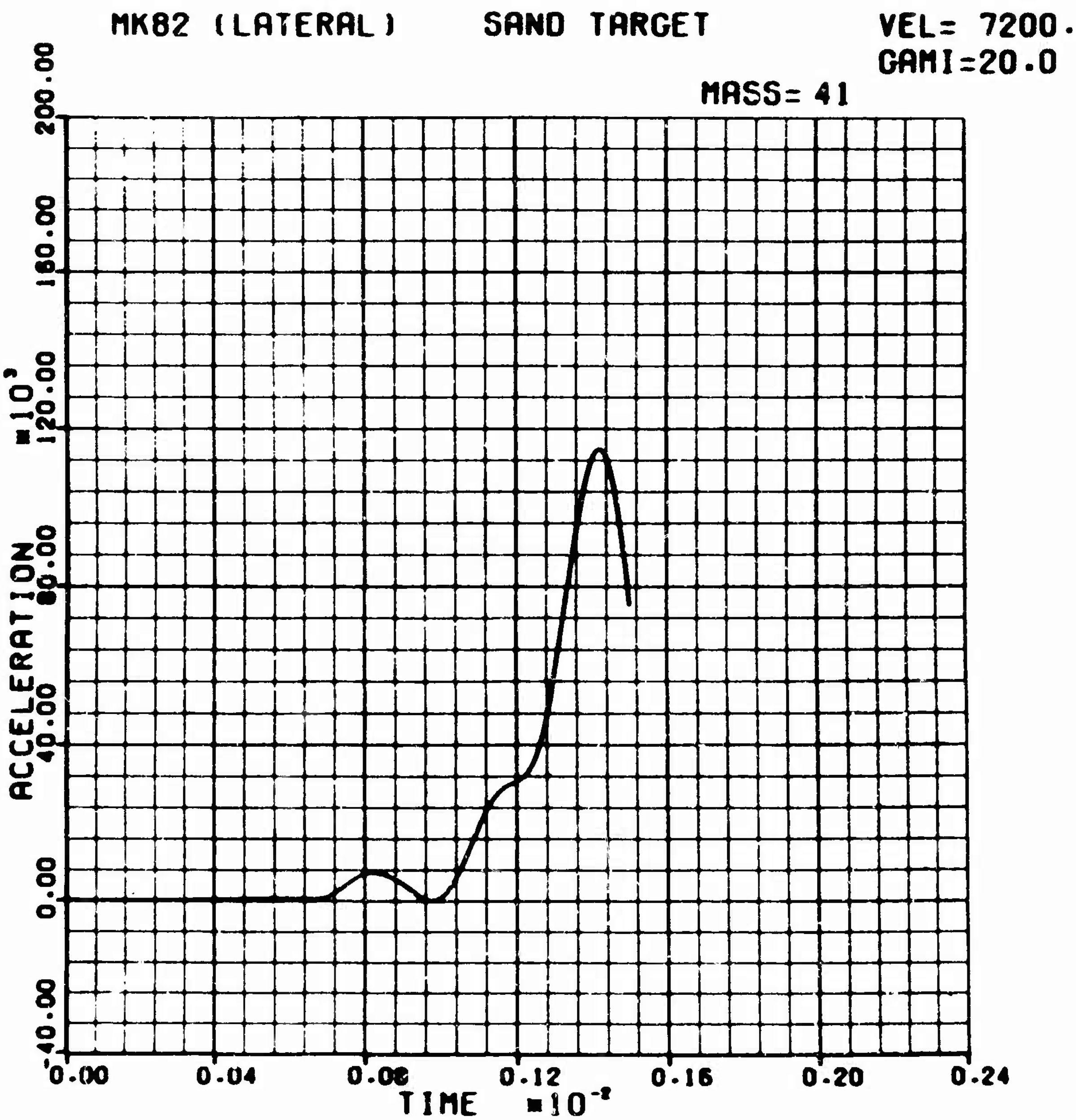


MK82 (LATERAL) SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 43
ACCELERATION ×10³
160.00
80.00
0.00
-80.00
-160.00
-240.00
-320.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME ×10⁻²

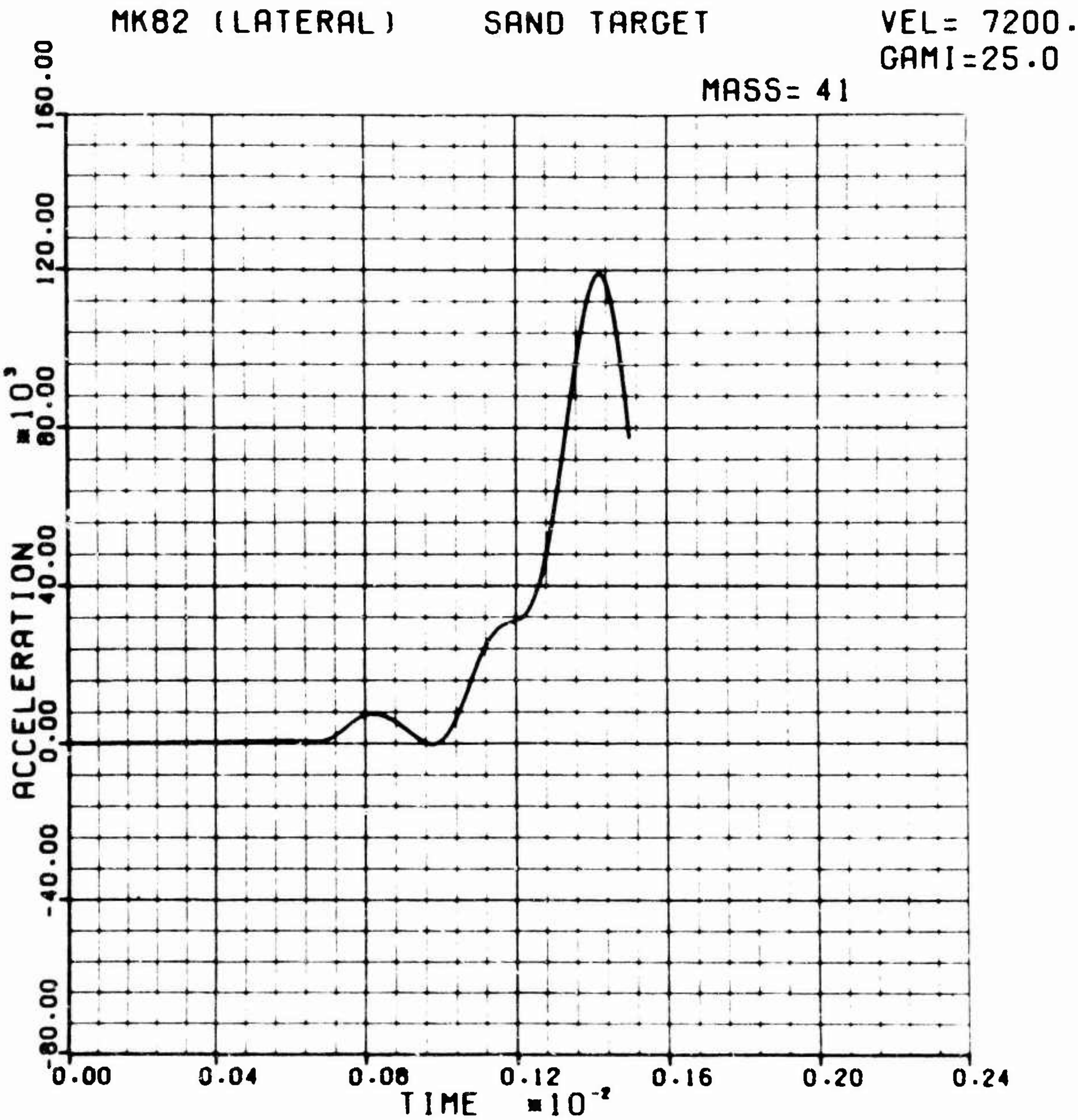

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 43
ACCELERATION *10³
120.00
40.00
-40.00
-120.00
-200.00
-280.00
-360.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



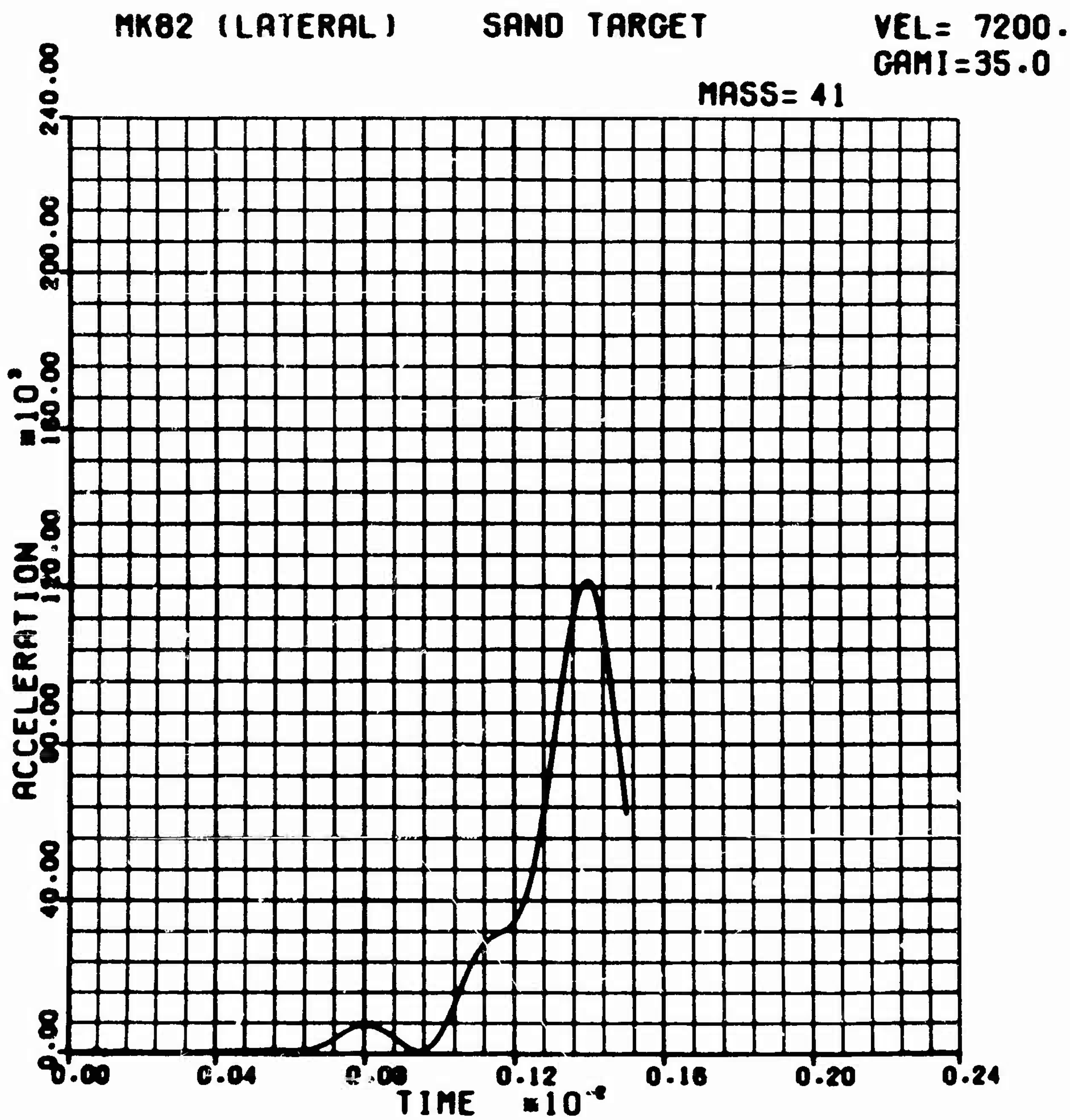
MK82 (LATERAL) SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 43
ACCELERATION *10⁴
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

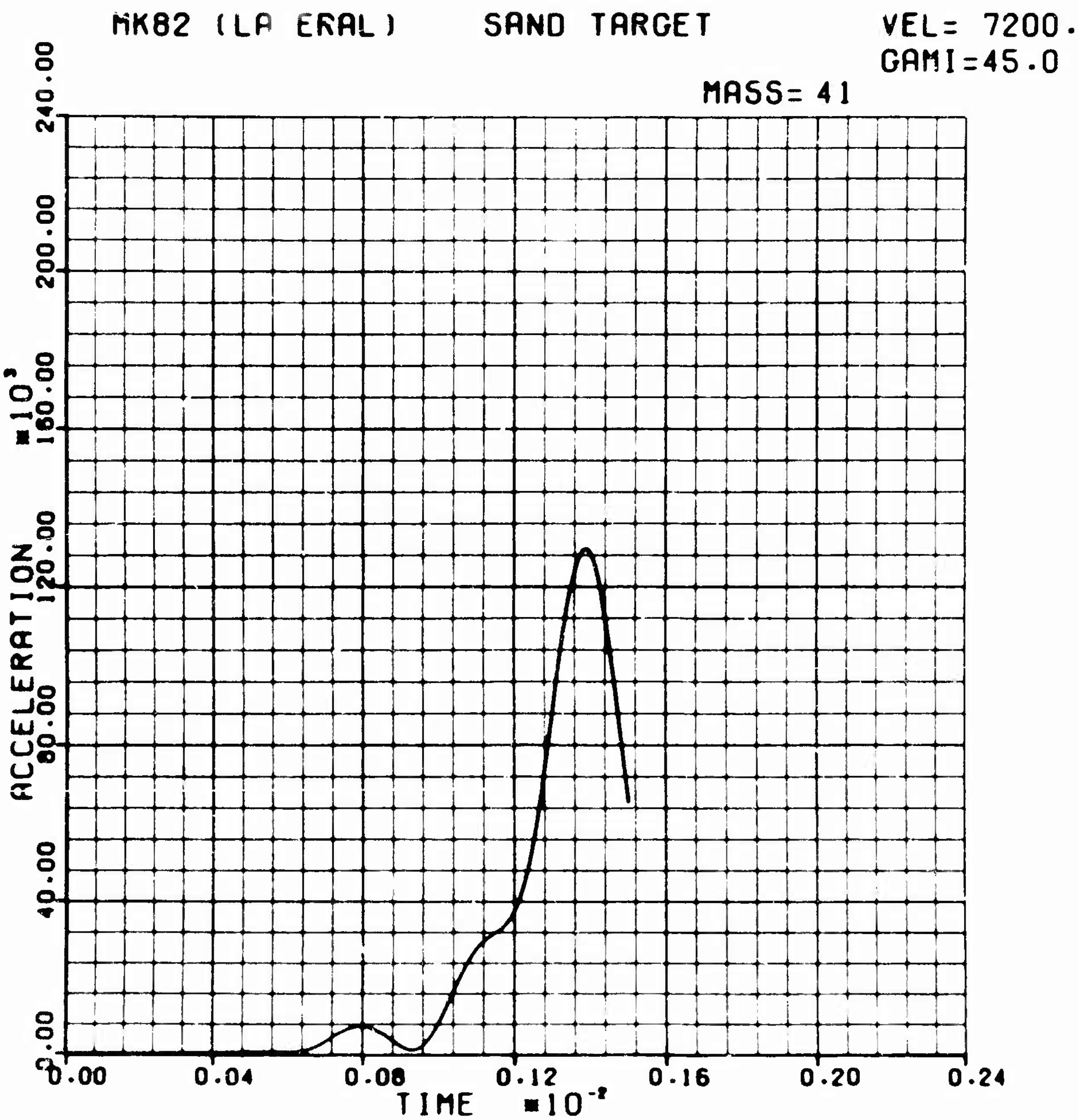


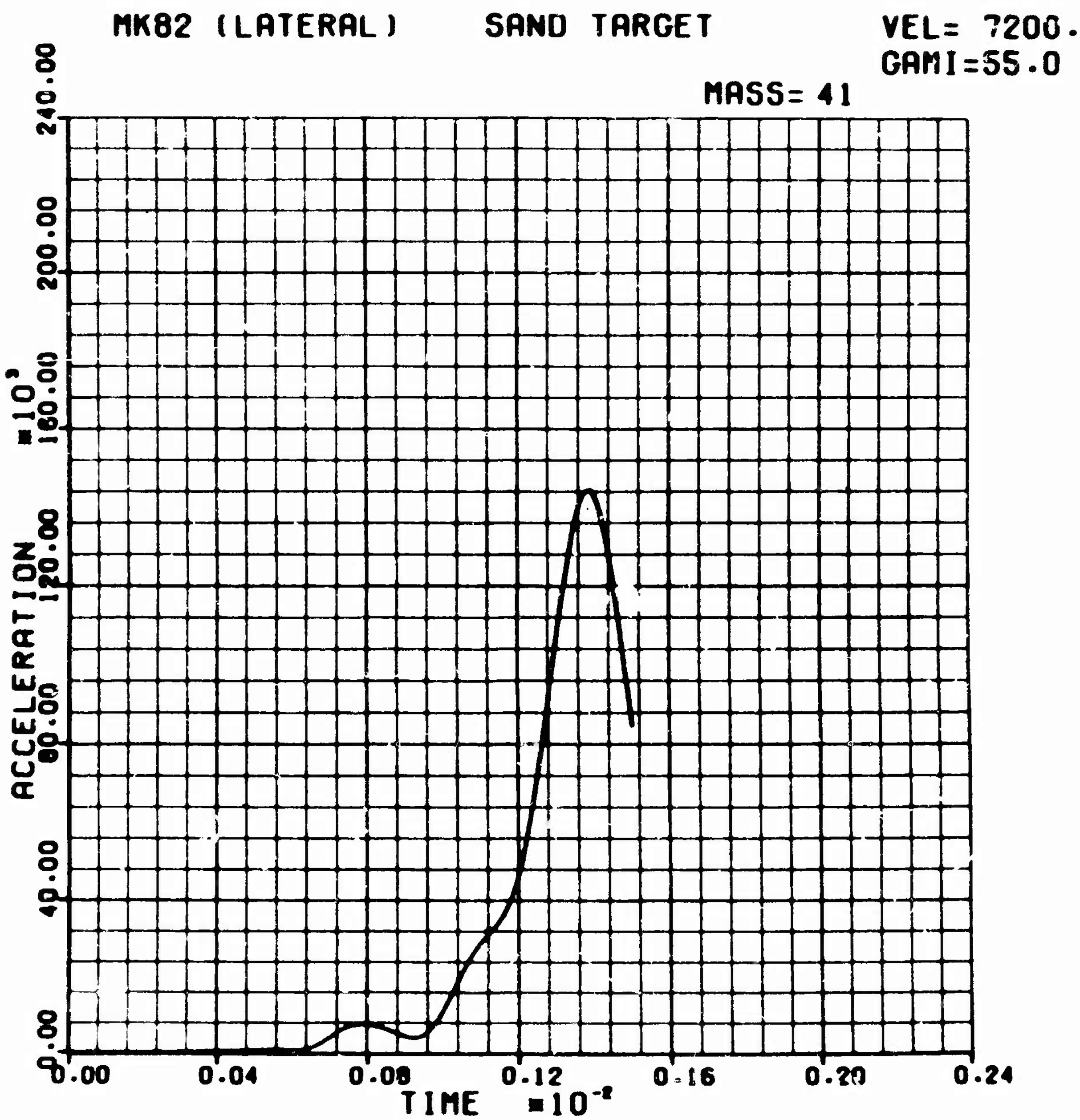
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 41
ACCELERATION *10³
200.00
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²



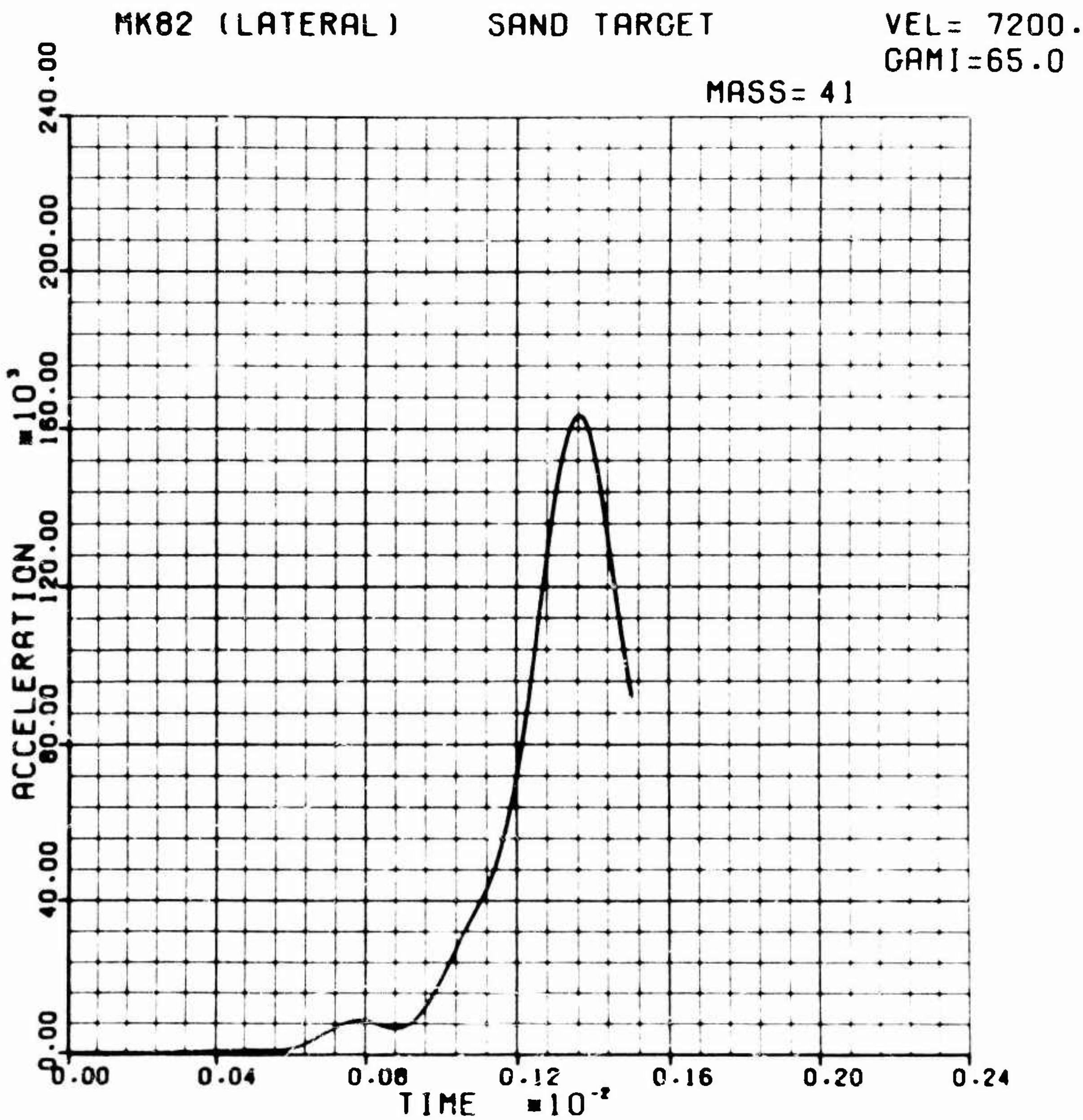
MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 41
ACCELERATION $*10^{3}$
160.00
120.00
80.00
40.00
0.00
-40.00
-80.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $*10^{-2}$

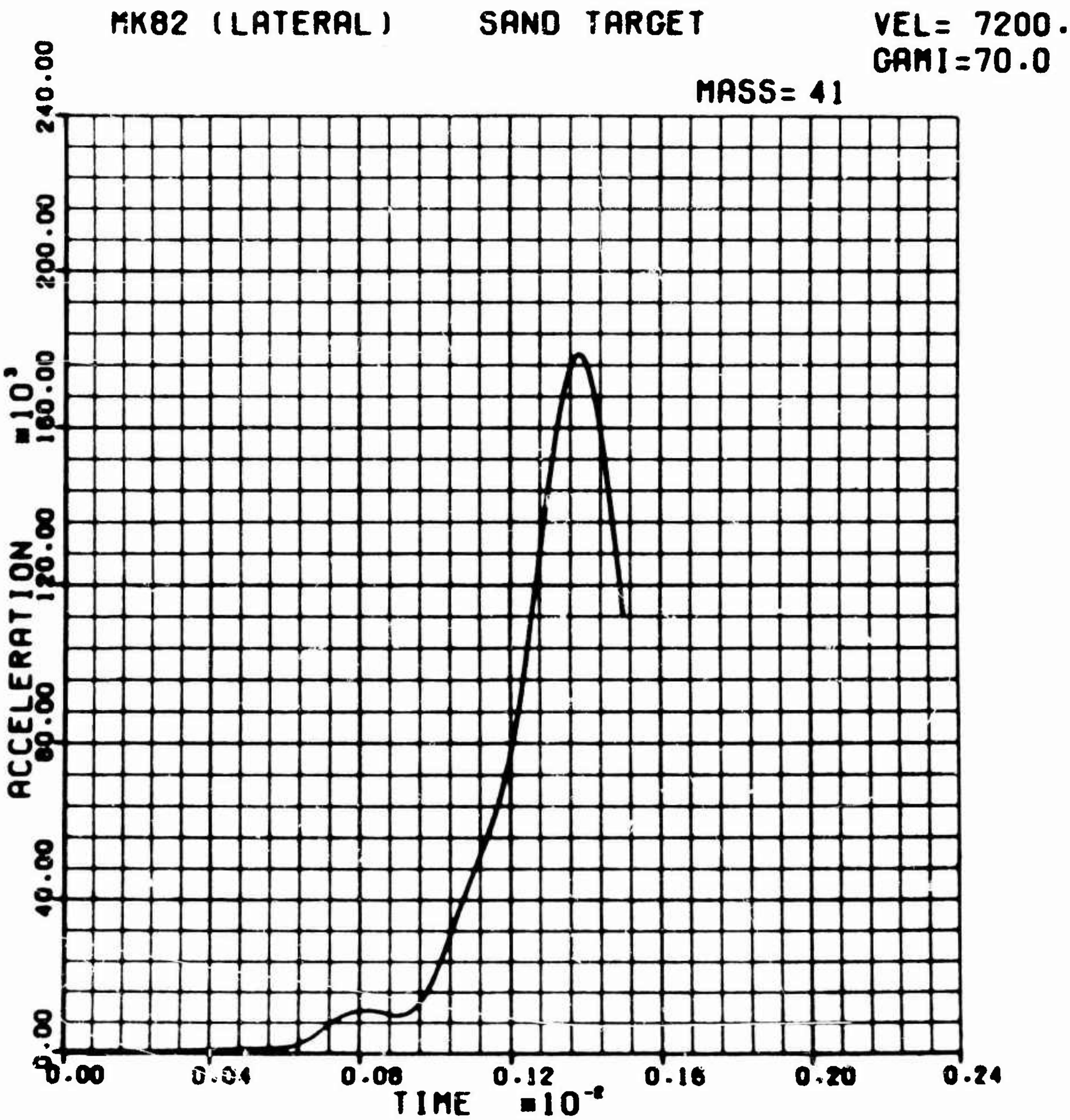

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 41
ACCELERATION ×10³
TIME ×10⁻²
0.00
40.00
80.00
120.00
160.00
200.00
240.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24

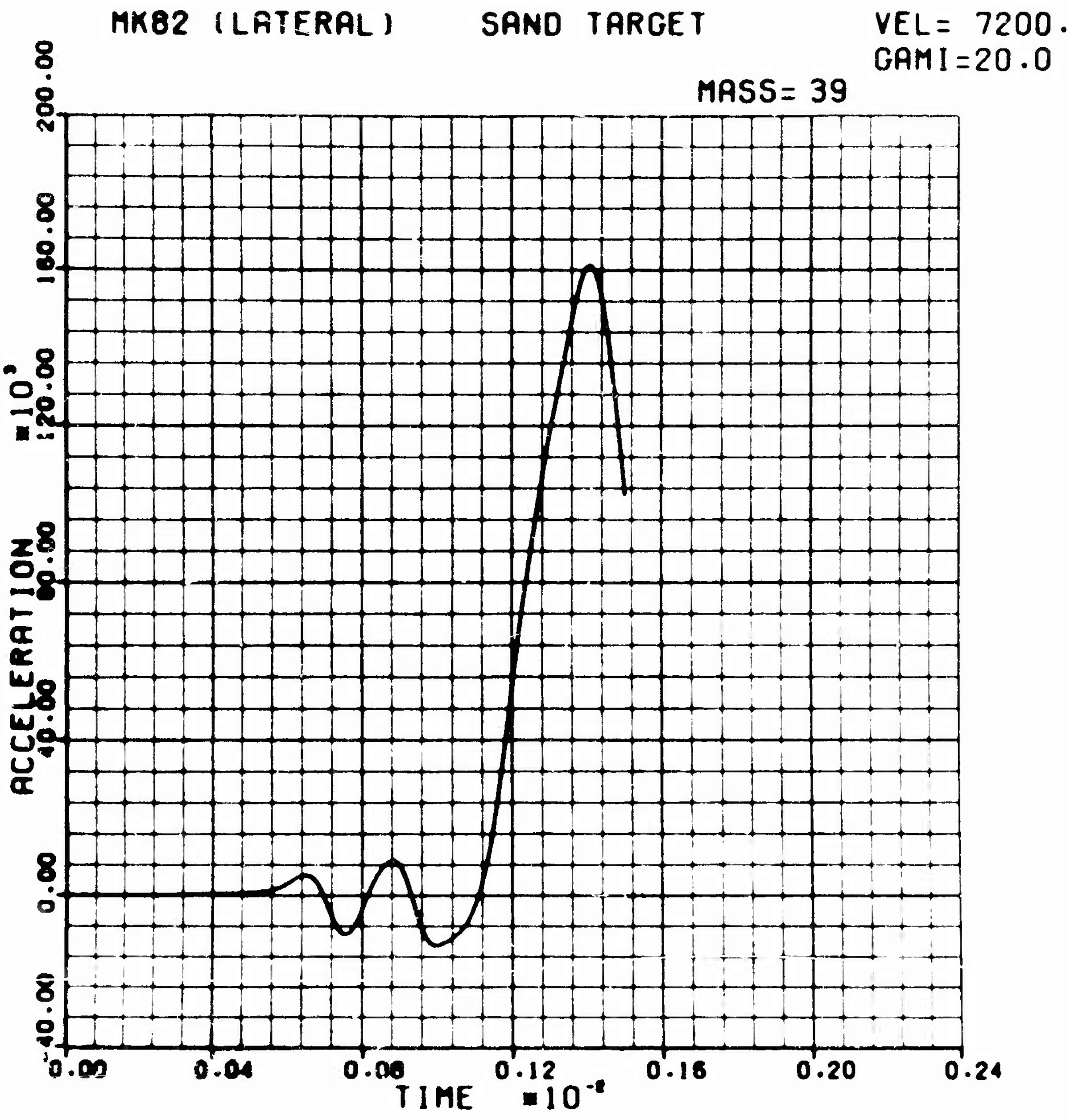

MK82 (LA ERAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 41
ACCELERATION *10³
0.00
40.00
80.00
120.00
160.00
200.00
240.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

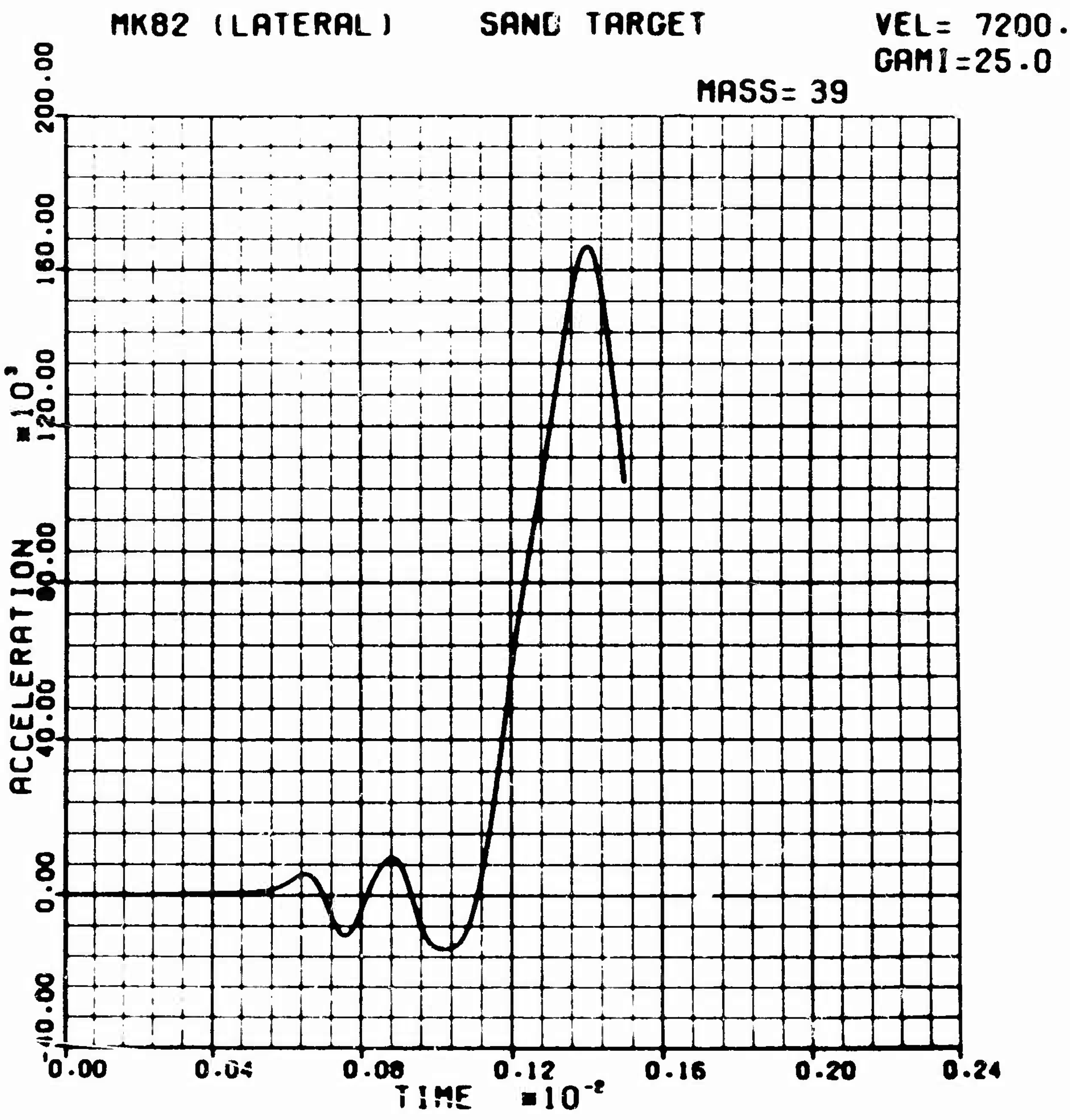


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 41
ACCELERATION $\times 10^{3}$
0.00
40.00
80.00
120.00
160.00
200.00
240.00
TIME $\times 10^{-2}$
0.00
0.04
0.08
0.12
0.16
0.20
0.24

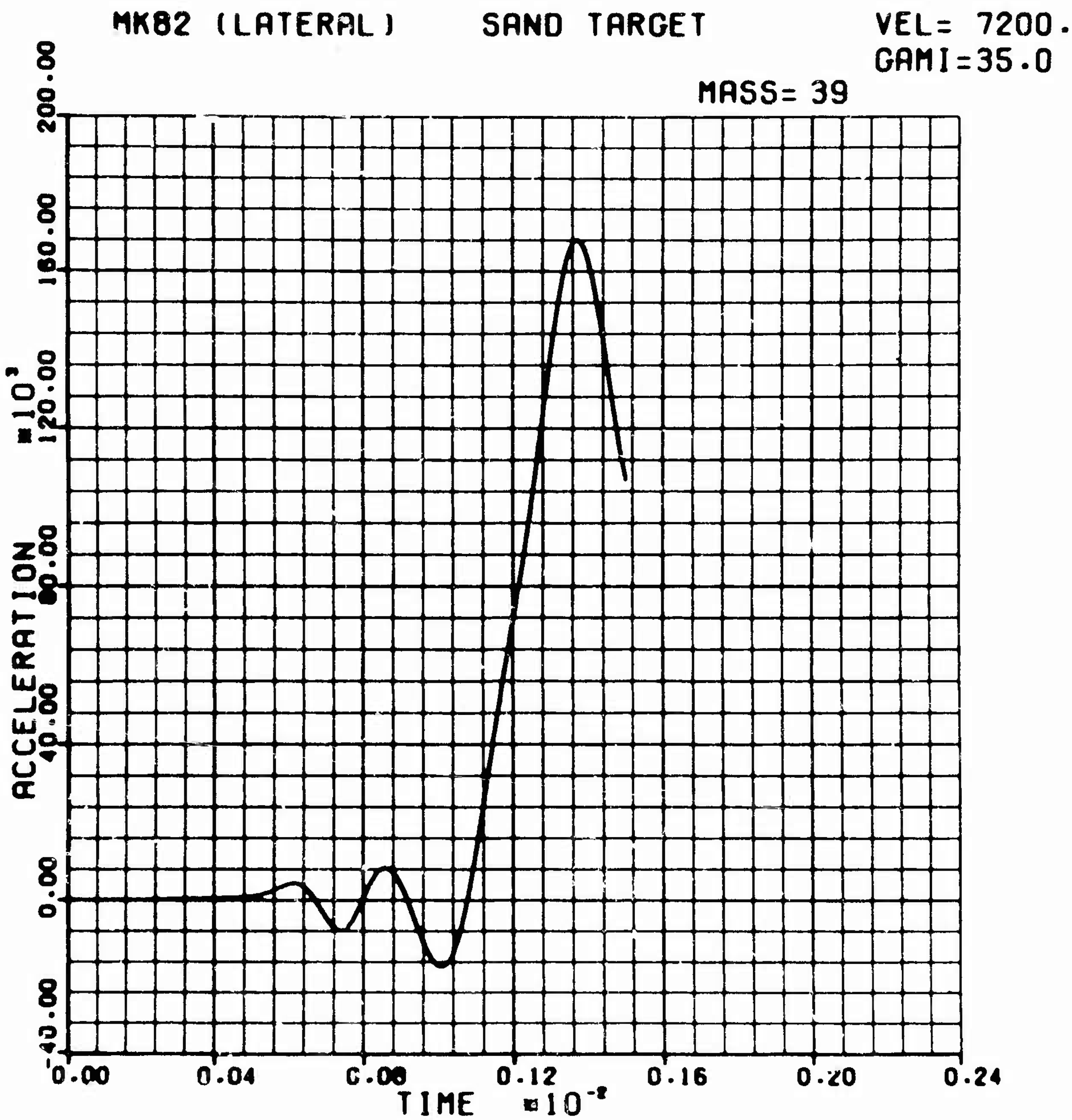

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 41
ACCELERATION *10³
0.00
40.00
80.00
120.00
160.00
200.00
240.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

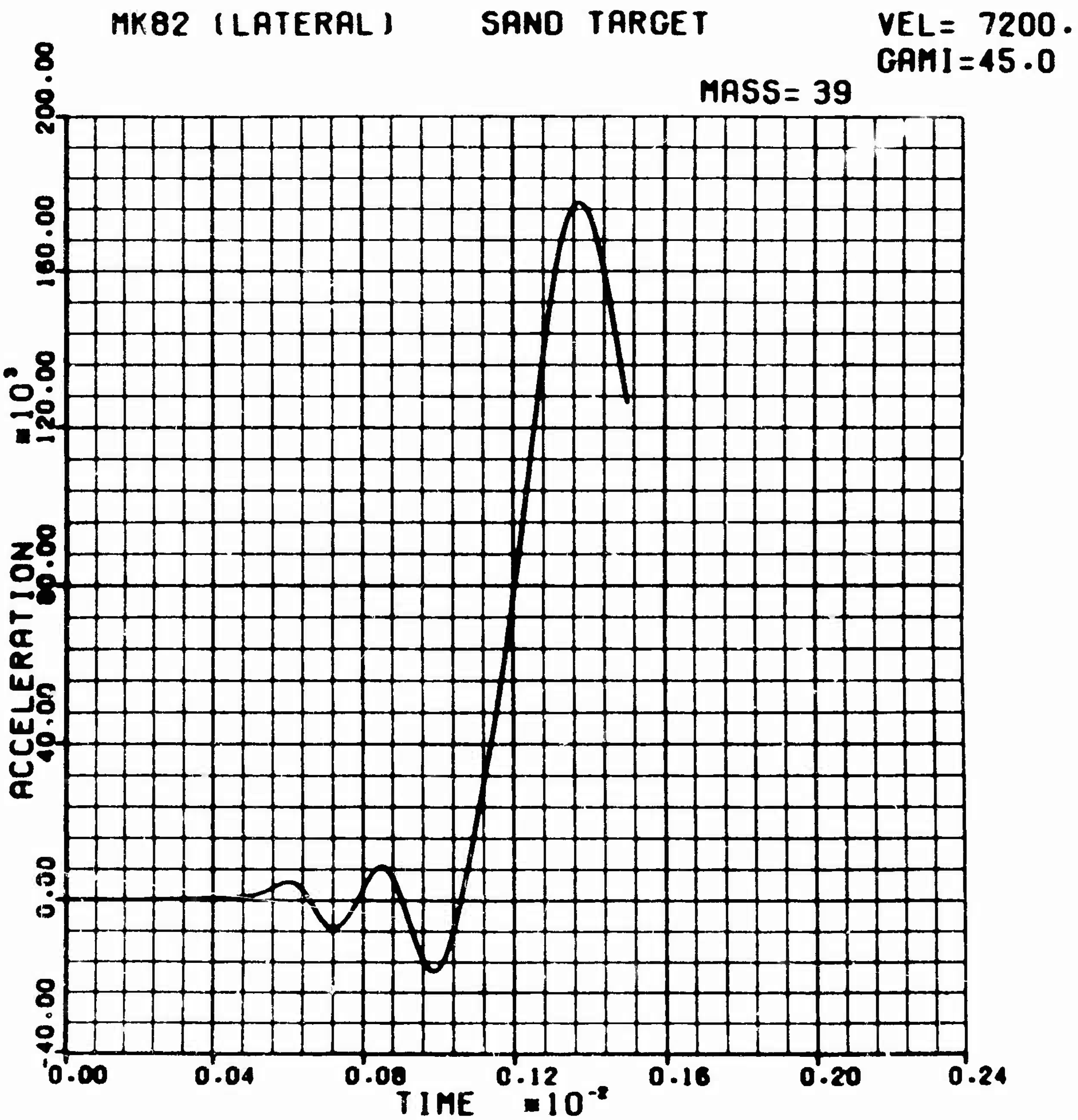

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 41
ACCELERATION *10³
0.00
40.00
80.00
120.00
160.00
200.00
240.00
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24

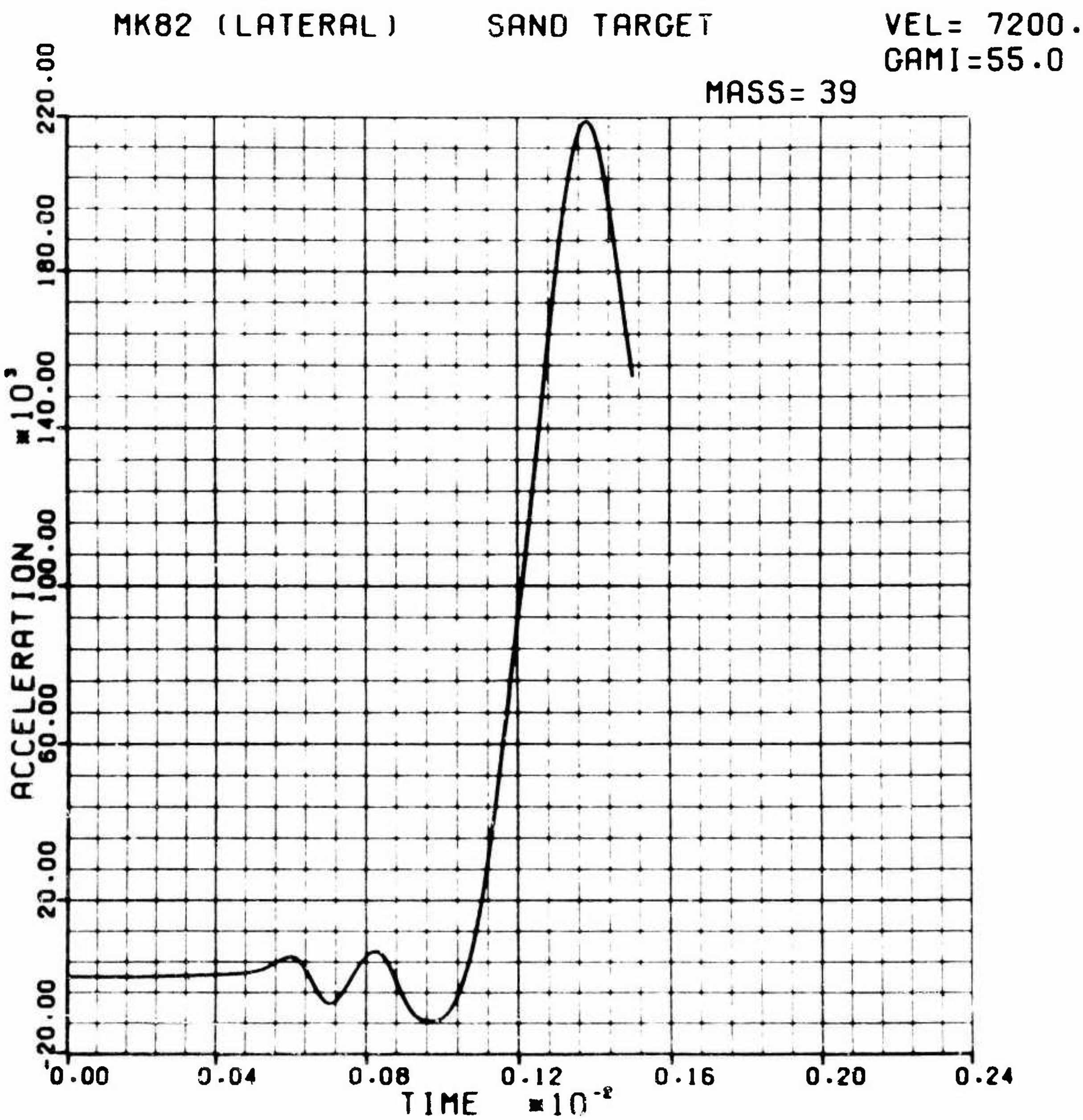

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=20.0
MASS= 39
ACCELERATION *10³
200.00
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

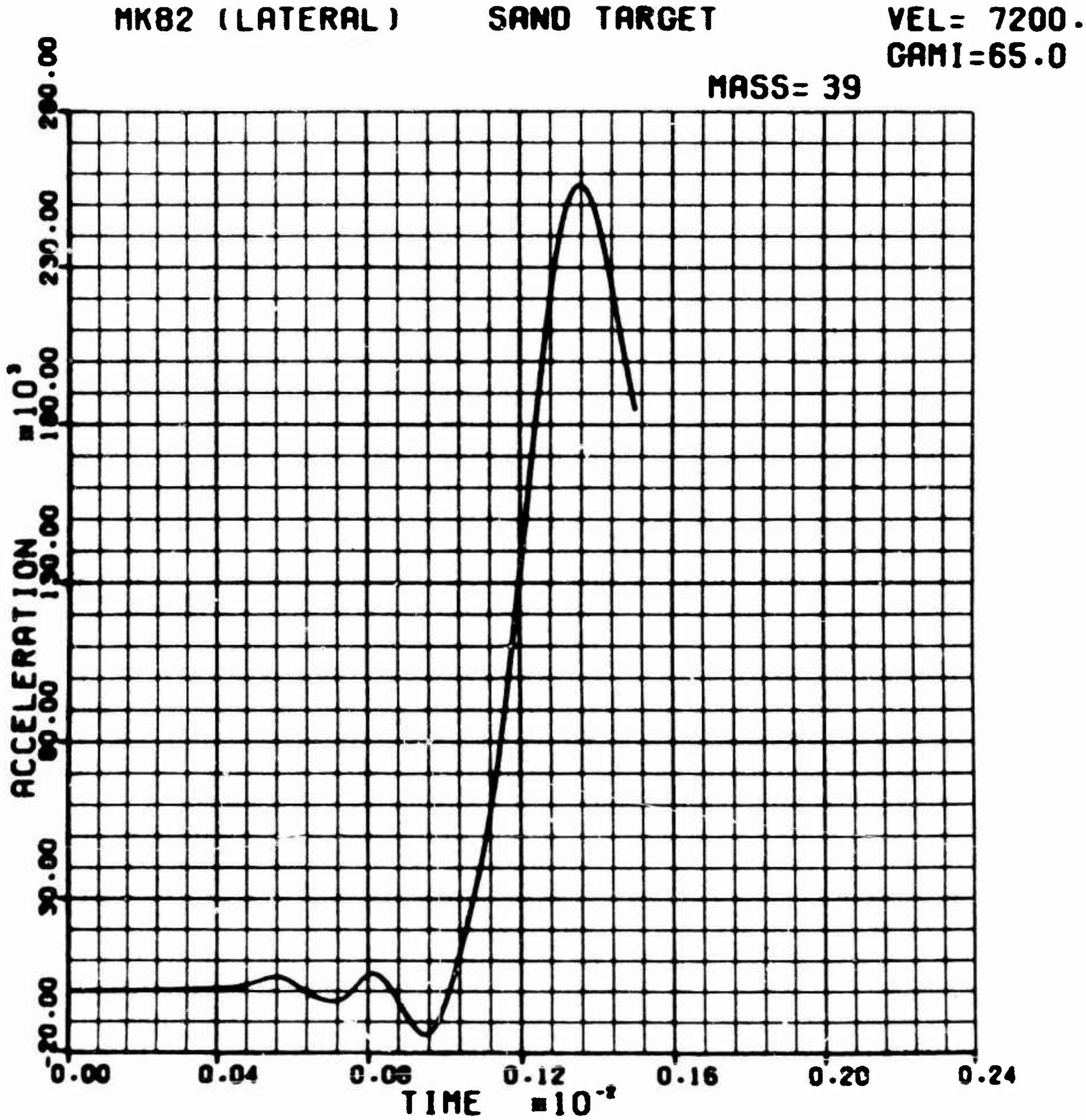


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=25.0
MASS= 39
ACCELERATION *10^3
200.00
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10^-2

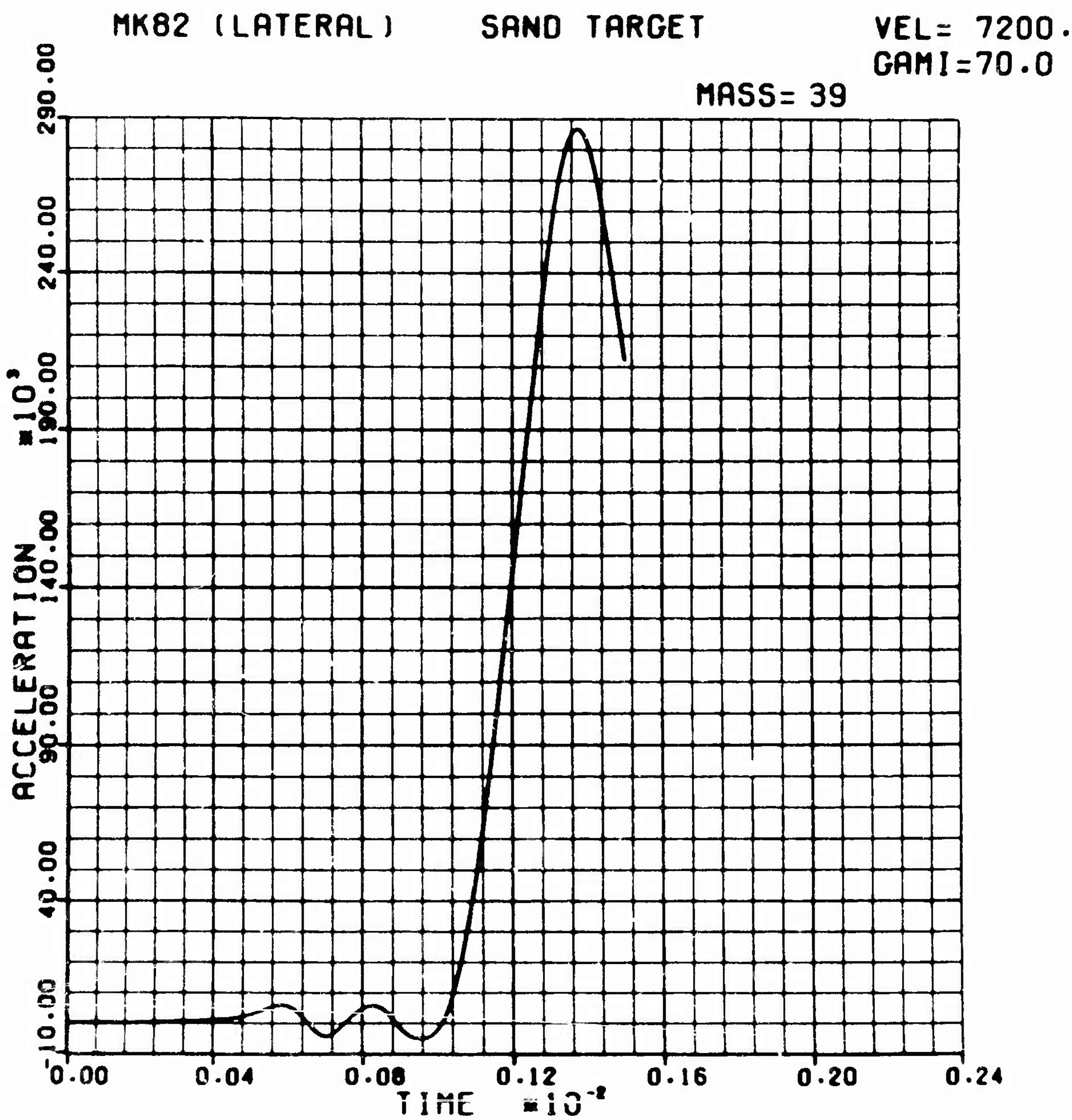

MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=35.0
MASS= 39
ACCELERATION $\times10^{3}$
200.00
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $\times10^{-2}$


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=45.0
MASS= 39
ACCELERATION *10³
200.00
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=55.0
MASS= 39
ACCELERATION $\times 10^3$
220.00
180.00
140.00
100.00
60.00
20.00
-20.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME $\times 10^{-2}$



MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=65.0
MASS= 39
ACCELERATION *10³
TIME *10⁻²
0.00
0.04
0.08
0.12
0.16
0.20
0.24


MK82 (LATERAL)
SAND TARGET
VEL= 7200.
GAMI=70.0
MASS= 39
ACCELERATION *10³
290.00
240.00
190.00
140.00
90.00
40.00
-10.00
0.00
0.04
0.08
0.12
0.16
0.20
0.24
TIME *10⁻²

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13. ABSTRACT

This research program was conducted to establish the deceleration environment experienced in the nose and tail fuze wells of the MK82 for bomb impacts into sand targets. The study was conducted for warhead impact velocities of 600, 900, and 1100 ft/sec and impact angles, from the vertical, from 20 to 70 degrees. The contractor's Two-Dimensional Impact and Penetration Computer Program was utilized to establish the time history of the loads applied to the MK82 during the impact and penetration event. This loading environment was then applied to a mathematical structural model of the MK82 to establish the deceleration environments experienced by both fuzes during the penetration event. The results of this analysis indicated that the flexibility characteristics of the warhead have a large influence upon the fuze well deceleration environments and generated deceleration magnification factors as high as 1.8.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Impact Parameters						
MK82 Math Model						
Loading Environments Analysis						
Structural Response Analysis						
155mm Fuze						
MK82 Fuze						
2-Dimensional Impact and Penetration Simulator						

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